DEVELOPMENT AND IMPLEMENTATION OF SURFACE TRAVERSE CAPABILITIES IN ANTARCTICA COMPREHENSIVE ENVIRONMENTAL EVALUATION

FINAL DRAFT

National Science Foundation
4201 Wilson Boulevard
Arlington, Virginia 22230

January 15, 2004

DEVELOPMENT AND IMPLEMENTATION
OF SURFACE TRAVERSE CAPABILITIES IN ANTARCTICA
COMPREHENSIVE ENVIRONMENTAL EVALUATION
FINAL DRAFT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 Purpose

This Comprehensive Environmental Evaluation (CEE) has been prepared by the Director of the Office of Polar Programs (OPP) of the National Science Foundation (NSF) to enable a decision to develop and implement surface traverse capabilities in Antarctica (i.e., the proposed action). The NSF manages and funds United States activities in Antarctica, and is responsible for the U.S. Antarctic Research Program (USAP) as well as the operation of three active U.S. research stations, numerous outlying facilities, and related logistical systems in support of scientific research activities in Antarctica.

This CEE contains information to permit informed consideration of reasonably foreseeable potential environmental effects of the proposed action and possible alternatives. Because the scope of individual traverse activities that may be performed by the USAP as a result of the proposed action will be dependent on the specific needs of each mission and cannot be accurately predicted in this CEE, representative examples of a re-supply and a science traverse have been used to identify and evaluate potential environmental and operational impacts. In addition, the affected environment described in this CEE (i.e., Ross Ice Shelf, Transantarctic Mountains, Polar Plateau) includes areas in Antarctica where surface traverse activities have been conducted in the past and represents areas where traverses may be reasonably expected to be performed by the USAP in the future. Should surface traverses be conducted in environmental settings that are substantively different than those as described in this CEE or involve different potential environmental receptors, supplemental environmental reviews would be performed.

1.2 Comprehensive Environmental Evaluation (CEE) Process

Proposed USAP actions in Antarctica are subject to the environmental impact assessment requirements of Annex I, Article 3 of the Protocol on Environmental Protection to the Antarctic Treaty, Environmental Impact Assessment, and the implementing regulations in the United States, Environmental Assessment Procedures for National Science Foundation Actions in Antarctica (45 CFR §641) (Code of Federal Regulations). These requirements specify that, for actions expected to have a *more than minor or transitory impact* on the Antarctic environment, a Comprehensive Environmental Evaluation (CEE) will be prepared.

In making this determination, the NSF must consider whether and to what degree the proposed action:

- Has the potential to adversely affect the Antarctic environment;
- May adversely affect climate and weather patterns;
- May adversely affect air or water quality;
- May affect atmospheric, terrestrial (including aquatic), glacial or marine environments;
- May detrimentally affect the distribution, abundance or productivity of species, or populations of species of fauna and flora;
- May further jeopardize endangered or threatened species or populations of such species;
- May degrade, or pose substantial risk to, areas of biological, scientific, historic, aesthetic or wilderness significance;
- Has highly uncertain environmental effects, or involves unique or unknown environmental risks; or
- Together with other actions, the effects of any one of which is individually insignificant, may have at least minor or transitory cumulative environmental effects.

Based on the preliminary environmental review of the scope of activities that may be performed as a result of the proposed action, and using the representative traverse examples and the above criteria, NSF has determined that the development and implementation of surface traverse capabilities in Antarctica may have a more than minor or transitory impact on the Antarctic environment, and has prepared this CEE accordingly. This CEE is consistent with the Protocol and U.S. implementing regulations including 45 CFR §641.18(b) which states that a CEE shall be a concise and analytical document, prepared in accordance with the range of relevant issues identified in the scoping process. It shall contain sufficient information to permit informed consideration of the reasonably foreseeable potential environmental effects of a proposed action and possible alternatives to that proposed action. Such base-line information shall include the following:

(1) A description of the proposed action (preferred alternative) including its purpose, location, duration and intensity;
(2) A description of the initial environmental state with which predicted changes are to be compared, and a prediction of the future environmental state in the absence of the proposed action;
(3) A description of the methods and data used to forecast the potential impacts of the proposed action;
(4) An estimate of the nature, extent, duration and intensity of the likely direct potential impacts of the proposed action;
(5) A consideration of the potential indirect or second order impacts from the proposed action;
(6) A consideration of potential cumulative impacts of the proposed action (preferred alternative) in light of existing activities and other known planned actions and available information on those actions;
(7) A description of possible alternatives to the proposed action, including the alternative of not proceeding, and the potential consequences of those alternatives, in sufficient detail to allow a clear basis for choice among the alternatives and the proposed action;
(8) Identification of measures, including monitoring, that could be employed to minimize, mitigate or prevent potential impacts of the proposed action, detect unforeseen impacts, provide early warning of any adverse effects, and carry out prompt and effective response to accidents;
(9) Identification of unavoidable potential impacts of the proposed action;
(10) Consideration of the potential effects of the proposed action on the conduct of scientific research and on other existing uses and values;
(11) Identification of gaps in knowledge and uncertainties encountered in compiling the information required by this paragraph (b);
(12) A nontechnical summary of the information included in the CEE; and
(13) The name and address of the person and/or organization which prepared the CEE, and the address to which comments thereon should be directed.

Where possible, the procedures and evaluation criteria described in the Guidelines for Environmental Impact Assessment in Antarctica (1) were also used in the preparation of this CEE. In addition, this document has been prepared consistent with the policies of the National Environmental Policy Act (NEPA) described in 40 CFR §1500-1508 and with National Science Foundation's implementing regulations for NEPA contained in 45 CFR §640. Applicability to NEPA is further defined by 45 CFR §641.14(e), which states that a CEE shall serve as an Environmental Impact Statement for purposes of Executive Order 12114, Environmental Effects Abroad of Major Federal Actions (44 FR 1957) (Federal Register).

1.3 Document Organization

Chapter 2 of this Comprehensive Environmental Evaluation provides the background information of surface traverses that have been conducted throughout the Antarctic continent. Chapter 3 provides a summary of the proposed action and possible alternatives. Chapter 4 describes the purpose and need of the proposed action and provides a description of typical traverse activities that may be performed including a discussion of the nature and intensity of the activities associated with re-supply and scientific traverses. Chapter 5 describes the affected environment (i.e., initial environmental state). Chapter 6 provides a detailed description of potential environmental impacts caused by the proposed action and addresses the following:

- A description of the methods and data used to forecast the potential impacts of the proposed action (45 CFR §641.18(b)(3))
- Consideration of the potential effects of the proposed action on the conduct of scientific research and on other existing uses and values (45 CFR §641.18(b)(10))
- Consideration of the potential indirect or second order impacts from the proposed action (45 CFR §641.18(b)(5))
- Consideration of potential cumulative impacts of the proposed action in light of existing activities and other known planned actions and available information on those actions (45 CFR §641.18(b)(6))
- Identification of unavoidable potential impacts of the proposed action (45 CFR §641.18(b)(9))

Chapter 7 identifies mitigating measures, including monitoring, that could be employed to “minimize, mitigate, or prevent potential impacts of the proposed action, detect unforeseen impacts, provide early warning of any adverse effects, and carry out prompt and effective response to accidents”. Chapter 8 identifies gaps in knowledge and uncertainties encountered in compiling the information presented in the CEE.

Chapter 9 summarizes the conclusions derived in this Comprehensive Environmental Evaluation of the development and implementation of surface traverse capabilities. Chapter 10 contains a nontechnical summary of the information included in this CEE and provides the name and address of the person and/or organization which prepared the CEE and who will address comments. Chapter 11 provides references to information and other documents used to prepare the CEE, and Chapter 12 includes appendices containing data that were used in the development of this CEE.

2.0 BACKGROUND OF SURFACE TRAVERSES IN ANTARCTICA

2.1 Introduction

The use of surface traverses is a major component in the history of Antarctic exploration for re-supply and science-related purposes. It continues to be a valuable tool to support research and various facilities on the continent.

Numerous traverses have been performed in Antarctica dating back to the earliest part of the 20th century, including the explorations performed by Robert Scott, Douglas Mawson, and Wilhelm Filchner. As technology progressed, mechanized transport was utilized and aircraft support resources were used to supplement and partially replace traverse activities. In recent years, numerous improvements in vehicle technologies, including features specifically designed or adaptable for polar conditions, have become available allowing surface transport to be a safe and reliable mode of travel.

2.2 Re-supply Traverses

Surface traverses were used extensively in the 1957-1958 International Geophysical Year (IGY) to establish and re-supply numerous Antarctic stations and large field camps. The surface traverses were often used to transport fuel, food, building materials and other supplies from coastal areas to remote facilities in the interior of the continent.

Table 2-1 identifies the characteristics of surface traverses that have been performed by seven nations for logistical support purposes for which documentation is available. Several of these nations routinely conduct traverses to re-supply facilities that operate on a long-term basis. For example, since the 1950s the Russians have routinely conducted 1,429 km traverses from Mirny Station to re-supply Vostok on the Polar Plateau. Re-supply traverses are also performed each year by South Africa to support station Vesleskarvet (i.e., SANAE IV) (see Figure 2-1) and by France and Italy to support the activities at the jointly-operated Antarctic station at Dome C (Concordia) (see Figure 2-2).

Table 2-1. Summary of Re-supply Traverses in Antarctica

Locations	Country	Region	Description
Casey - AWS	Australia	Wilkes Land	In April 2002, Caterpillar D7G, D6, and D5 tractors were used to install automatic weather stations at various locations in East Antarctica over a 600 km roundtrip
Moore Pyramid, Farely Massif, Mount Cresswell	Australia	Mac Robertson Land	During the 1970s a series of traverses, supplemented with fixed wing aircraft and helicopters, established field bases in the Prince Charles Mountains to support remote field programs in the region.
Mount King	Australia	Enderby Land	Similar to the program in the Prince Charles Mountains, traverse resources were used to establish a base to support nearby field operations.
Wilkes- Vostok	Australia	Wilkes Land	A 3,000 km roundtrip traverse from Wilkes to the abandoned Vostok station and return, using two Caterpillar D4 tractors, was performed in 1962.
Mawson – Prince Charles Mountains	Australia and Germany	Mac Robertson Land	In support of the Prince Charles Mountains Expedition of Germany-Australia (PCMEGA), a traverse over an established route was performed during 2002 with the specific purposes of placing a fuel depot at LGB6, located 250 km from Mawson. The traverse comprised three tractors towing two support

Table 2-1. Summary of Re-supply Traverses in Antarctica

Locations	Country	Region	Description
			modules and three sledges containing over 300 drums of fuel. The traverse was staffed by 6-8 people and took six weeks to complete.
Mawson – Mount Cresswell	Australia and Germany	Mac Robertson Land	A second PCMEGA traverse was conducted during the 2002-03 austral summer and comprised a 1,000 km roundtrip conducted to deliver 90,000 liters of fuel to the base at Mount Cresswell. A crew of five personnel operated three Caterpillar D7s and one Haaglund towing two support modules and six cargo sledges. The last 200 km of this traverse were over an uncharted route.
Cape Prudhomme - Dome C (Concordia)	France and Italy	Polar Plateau	Traverses have been conducted to Dome C over a period of eight years. Up to seven Caterpillar Challengers, two each Kassbohrer PB330, and one Kassbohrer PB270 and up to seven associated sleds and trailers per tractor were used to support construction of the new Concordia station from Dumont d'Urville station located 1,100 km away, and continue to be used to re-supply the facility. Up to three traverses per year have been conducted, with up to 120 tonnes of cargo transported in each traverse while consuming approximately 80,000 liters of fuel. Each roundtrip takes approximately 25 days.
Neumayer - EPICA	Germany	Queen Maud Land	Up to eight Kassbohrer Pisten Bully tractors towing living containers and sledges were used to transport 325 tonnes of supplies for drilling activities at field camp and remote field locations. Since 2000, up to two traverses per season have been conducted.
Suyowa - Dome Fuji	Japan	Queen Maud Land	In conjunction with International Trans Antarctic Science Expedition (ITASE) activities in 1997, a re-supply traverse was conducted to Dome Fuji Station, covering a distance of 1,000 km.
Mirny-Vostok	Russia	Wilkes Land	Two inland bases were established using traverse resources in 1957 and 1958; the Vostok station near the Geomagnetic Pole and the other, the former Sovietskaya station, at the Pole of Inaccessibility. Regular re-supply of Vostok Station has been performed using tracked vehicles.
EBase/SANAE III - SANAE IV	South Africa	Queen Maud Land	The Vesleskarvet (i.e., SANAE IV) base was constructed from 1993 to 1998 using Caterpillar Challengers and Caterpillar D6 tractors to transport 800 tonnes of construction materials 160 km from EBase (i.e., SANAE III). Up to five tractors are used to conduct one or two annual re-supply traverses per season. Refueling of traverse equipment is supported by a field cache consisting of a 3,000-liter fuel tank.
Little America – Byrd	United States	Marie Byrd Land	Caterpillar D8 tractors were used to transport supplies to Byrd Station from the former coastal station at Little America during the 1957-1958 austral summer.

Figure 2-1. Re-supply Traverse for SANAE IV

Source: South African National Antarctic Expedition (http://www.geocities.com/sanaeiv/index.html)

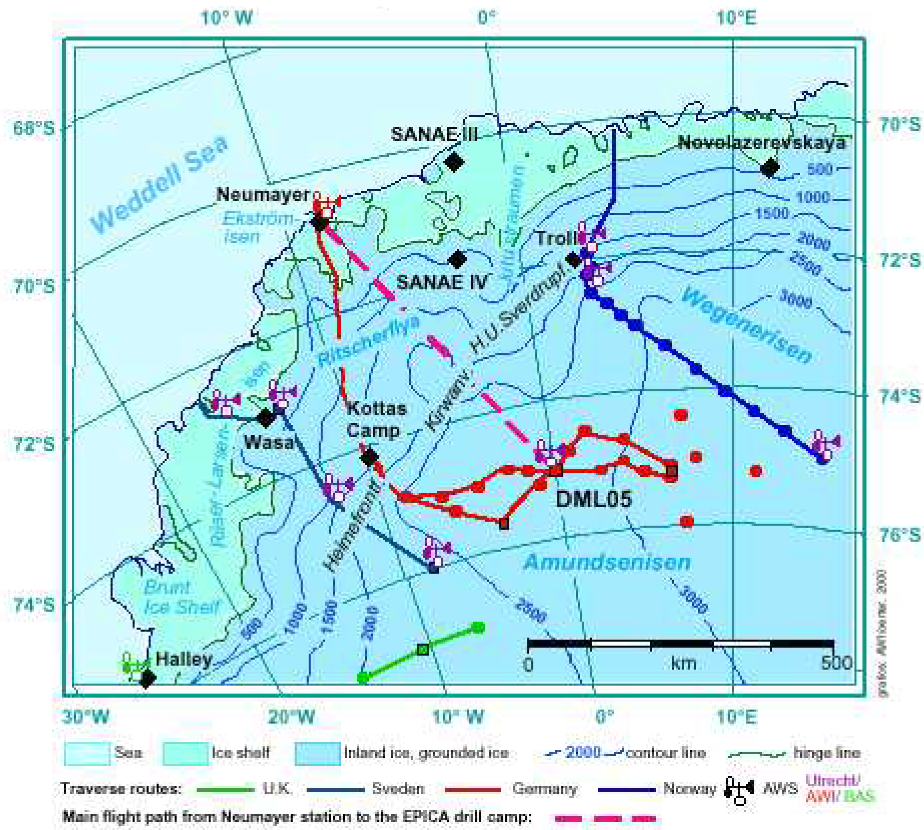
Figure 2-2. Re-supply Traverse for Concordia Station

Source: Antarctic Sun

Traverses have been used by the Australian National Antarctic Research Expeditions (ANARE) since Australia set up its first Antarctic station at Mawson in 1954, although most of the earlier traverses were comprised of dog sledges and were supported by airlift. In 1962, ANARE conducted a 3,000 km roundtrip traverse between the former U.S. Wilkes Station in Vincennes Bay (near modern-day Casey Station) and Vostok Station. This was the earliest traverse to demonstrate the potential of mechanized transport for remote, long-range, field travel. During the 1970s, ANARE established field bases in the Prince Charles Mountains and Enderby Land using a series of traverses supplemented with support by fixed wing aircraft and helicopters. More recently, ANARE conducted a traverse from Casey Station to establish various field research locations in East Antarctica and completed a 1,000 km roundtrip traverse in conjunction with Germany from Mawson Station to the Prince Charles Mountains to deliver fuel as part of the Prince Charles Mountains Expedition of Germany – Australia (PCMEGA).

Surface traverse resources were recently used to support a multinational research effort in Dronning Maud Land known as the European Project for Ice Coring in Antarctica (EPICA). The project included a series of traverses to transport bulk materials from coastal facilities (e.g., Neumayer Station) along shelf and inland ice sheets to the drilling sites (Figure 2-3).

Figure 2-3. Re-supply Traverse Routes for EPICA

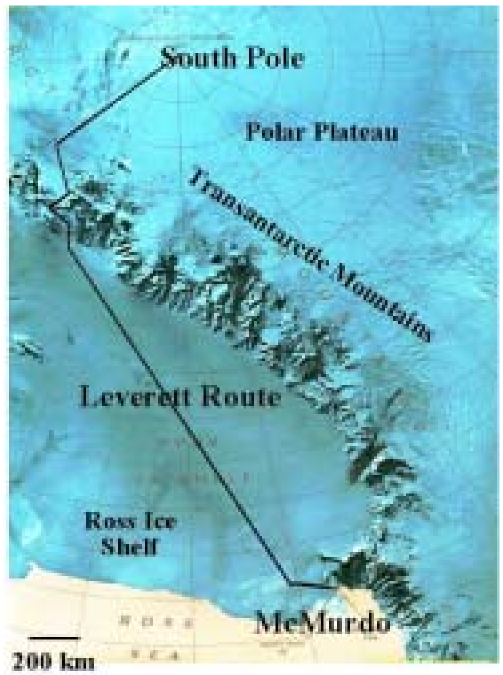


Source: Comprehensive Environmental Impact Evaluation for Recovering a Deep Ice Core in Dronning Maud Land, Antarctica (reference 18)

The United States used traverses during the 1950s through the 1970s for scientific and exploratory research applications but did not develop the resources for major re-supply missions. In recent years, the USAP has used small-scale surface traverses to transport supplies to various outlying facilities near McMurdo Station including the Pegasus Runway (25 km), the Black Island Telecommunications facility (35 km), and the Marble Point Refueling Facility (100 km). The USAP conducts these smaller traverses using existing heavy equipment and sleds and trailers.

While the USAP does not have the resources to perform more complex or longer distance re-supply traverses, a feasibility and engineering study is underway to evaluate a surface route and equipment requirements to transport cargo from McMurdo Station to the Amundsen-Scott Station at the South Pole (Appendix A). A potential traverse route crossing the Ross Ice Shelf and ascending Transantarctic Mountains at the Leverett Glacier to the Polar Plateau (Figure 2-4) is currently being evaluated by the USAP as a "proof of concept" demonstration. This effort is expected to take place over the next several austral summer seasons. Based on experience gained from the proof of concept study and from previous traverses conducted in Antarctica, the USAP intends to develop a more robust traverse capability to supplement current airlift resources and thus enhance research opportunities in Antarctica.

Figure 2-4. Proof of Concept Traverse Route from McMurdo Station to the South Pole



2.3 Scientific Traverses and Surface-Based Surveys

Traditionally, most surface traverses conducted in Antarctica have been specifically designed for science-related and data collection purposes. Over 90 years ago, the earliest surface traverses focused on exploration and mapping goals and were performed by expeditions from Britain, Norway, Germany, and Australia. At that time, the traverses were comprised of dog-sleds and human-drawn sledges. The first use of a flagged route over snow-covered terrain is believed to have occurred in 1912 by Douglas Mawson leading the Australasian Antarctic Expedition during the survey and mapping of George V Land.

The first documented use of mechanized equipment such as tractors for a science-related surface traverse was performed by Richard Byrd during the 1933-1934 austral summer. The traverse involved ground-based geology, meteorology, biology, and atmospheric studies throughout Marie Byrd Land. Because of the emergence of aircraft to support Antarctic exploration and the occurrence of World War II, few science-related traverses were performed during the 1930s and 1940s. One series of science-related traverses which was performed between 1935 and 1937 included the British Graham Land Expedition that involved aerial and sledge surveys on the Antarctic Peninsula.

Major science-related traverse and surface-based survey activities began in earnest during the 1950s. Between February 1950 and January 1952, a Swedish-British-Norwegian scientific expedition based at the temporary Maudheim Station conducted surface-based glaciological and geological surveys in the interior of Queen Maud Land. The International Geophysical Year (IGY) from 1 July 1957 to 31 December 1958 was a great cooperative endeavor by the world's scientists to improve their understanding of the earth and its environment. Much of the field activity during the IGY took place in Antarctica, where 12 nations established some 60 research stations. A notable investigation involved the British Commonwealth Trans-Antarctic Expedition, a joint British-New Zealand project, led by Sir Vivian Fuchs and Sir Edmund Hillary. This investigation was designed to complete an entire cross-section of the continent and collect seismic and magnetic data. In late 1957, two teams began at different ends of the continent (Weddell Sea, Ross Sea), met at the South Pole, then returned to Scott Base on Ross Island.

During the IGY, the United States established six research stations: Little America, Hallett, South Pole, Byrd, Wilkes (on the coast of Wilkes Land, East Antarctica) and Ellsworth (on the Filchner Ice Shelf). Naval Air Facility, McMurdo Sound (now McMurdo Station), was set up as a logistics base that was used to re-supply the South Pole. The United States contributed to the IGY by making several long scientific traverses to collect data for research in glaciology, seismology, gravimetry, and meteorology.

Table 2-2 identifies science-related surface traverses and ground-based surveys that have been performed between 1950 and 1999 by 10 countries, including the United States. Several of these traverses were multi-year efforts between several locations, circular routes, or spurs from a central location. At least six of these expeditions utilized the South Pole as an endpoint. One of the most extensive science-related traverses was conducted by the Australians in the Lambert Glacier Basin traveling over 4,500 km.

A recent and extensive series of science-related traverses was conducted throughout East and West Antarctica between 1999 and 2003 for the International Trans Antarctic Scientific Expedition (ITASE). The ITASE traverses were designed to build upon the existing coverage of glaciological traverses conducted since the 1950's and were conducted jointly by 14 different nations (Figure 2-5).

Although the United States conducted various surface traverses during the 1950s and 1960s (Table 2-2), the USAP has conducted few science-related traverses since this period. There were many reasons for the shift from the traverse mode of operation, the most significant being the availability of ski-equipped airlift resources to support field camps in remote areas. However, the USAP's participation in the recent ITASE traverse activities has reaffirmed the value of surface-based scientific research supported by mobile facilities.

Table 2-2. Summary of Scientific Traverses and Surface-based Surveys in Antarctica

Mission ID	Region	Description	Data Type	Country
TRAVERSES				
RIS-5760	Ross Ice Shelf	US seismic reflection shooting over the Ross Ice Shelf between October 1957 and March 1960. Three traverses undertaken by United States parties including the Ross Ice Shelf traverse Oct 1957 - April 1958, Victoria Land traverse Oct 1958 - Jan 1959, Discovery Deep traverse Feb and March 1960.	Seismic reflection & gravity	US
LAMBERT-8995	Lambert Glacier basin	ANARE Lambert Glacier Basin traverse 1989/90 to 1994/95. Study of the mass budget and dynamics of the interior basin. Traverses were conducted from Davis to Mawson, around the top of Lambert Glacier Basin, and back to Davis. The 1994/95 traverse completed a 4,500 km journey.	Ground-based RES	AU
WESTANT-5759	Marie Byrd Land and the Ellsworth Mountains	US seismic reflection shooting, Marie Byrd Land, Ellsworth Land and the Horlick Mountains at 30 nautical mile (55.5 km) intervals, during three traverses in West Antarctica between January 1957 and January 1959.	Seismic reflection & gravity	US
MARIEBYRD-5960	Marie Byrd Land	US northwest Marie Byrd Land traverse 1959-60, ice thickness from combined gravity and seismic observations.	Seismic reflection & gravity	US
MCMPOLE-6061	Victoria Land, Plateau, South Pole	US seismic soundings carried out in a traverse from McMurdo Station to the South Pole in 1960-61.	Seismic reflection & gravity	US
SPQMLT-6468	Queen Maud Land	US seismic, gravimetric and electromagnetic observations in three reconnaissance traverses from South Pole to Queen Maud Land (1964/65, 1965/66, 1967/68).	Seismic reflection & gravity	US
VLT1-5859	Victoria Land	US seismic observations, Victoria Land traverse No. 1, made on oversnow traverse from the head of the Skelton Glacier to 132E.	Seismic reflection	US
VLT2-5960	Victoria Land	US seismic observations, Victoria Land traverse No. 2, made on oversnow traverse in the Victoria Land plateau.	Seismic reflection	US
PENINSULA-6162	Ellsworth Land, Antarctic Peninsula	US seismic and gravity measurements obtained during the Antarctic Peninsula oversnow traverse of 1961-62.	Seismic reflection & gravity	US
JARE-6971	West Enderby Land	JARE 10-11 oversnow traverse in the Mizuho Plateau-West Enderby Land, 1969-71. Observations of ice thickness obtained using a radio echo sounder. Additional measurements obtained from seismic soundings and gravimetric methods. Includes seven routes A,B,C,S,W,X,Y.	Ground-based RES	JP
JARE-8283	Queen Maud Land	JARE 23 oversnow traverse in East Queen Maud Land along line of Shirase Glacier, Yamamoto Mountains, 1982-83. Observations of ice thickness obtained using a radio echo sounder. Includes routes IM, YM,SS,SY,H,Z	Ground-based RES	JP
JARE-8384	Queen Maud Land	JARE 24 oversnow traverse in East Queen Maud Land extending work or East Queen Maud Land Glaciological project, 1983-84. Includes route KR.	Ground-based RES	JP
JARE-8586	Queen Maud Land	JARE 26 oversnow traverse in East Queen Maud Land toward the inland plateau and Sor Rondane Mountains, 1985-86. Includes routes ID, DF.	Ground-based RES	JP
JARE-8687	Queen Maud Land	JARE 27 oversnow traverse in East Queen Maud Land extending work or East Queen Maud Land Glaciological project, 1986-87. Includes routes SZ,NY,YG6,RY,L.	Ground-based RES	JP
RONNE-9495	Ronne Ice Shelf	BAS 2300 km traverse across part of the Ronne Ice Shelf during the 1994-95 season. Seismic reflection stations at 15 km intervals.	Seismic reflection	UK

Table 2-2. Summary of Scientific Traverses and Surface-based Surveys in Antarctica

Mission ID	Region	Description	Data Type	Country
TAE-5758	Upper Plateau - West Antarctica, South Pole, Victoria Land	Seismic reflection survey conducted by Commonwealth Trans-Antarctic Expedition, 1955-58. Surface traverse from Shackleton Base on the Filchner Ice Shelf through the South Pole and on to Scott Base.	Seismic reflection	UK
GEORGEVI-8485	George VI Ice Shelf, Antarctic Peninsula	Seismic measurements across George VI Ice Shelf supplemented by ground base RES measurements, 1984/85. Traverses were run perpendicular to the regional geology. 101 seismic stations and 210 RES measurements.	Seismic reflection & RES	UK
ANARE-5759	Kemp Land	ANARE seismic and gravity survey during the period of the IGY (1957-59) inland of Mawson Station, Kemp Land. Ice thickness measurements made on two regional traverses.	Seismic reflection & gravity	AU
BELGE-5960	Dronning Maud Land	1959-60 Belgian Antarctic Expedition seismic traverse in Dronning Maud Land from the King Baudouin base to the Sor Rondane Mountains.	Seismic reflection	BE
SOUTHPOLE-6263	South Pole traverse	Seismic investigations on a US oversnow traverse between South Pole and the Horlick Mountains during the 1962-63 season.	Seismic reflection	UK
BELGEDUTCH-6566	Sor Rondane Mountains, Dronning Maud Land	Oversnow gravity traverses carried out in the major glaciers draining the Sor Rondane Mountains in 1966 by the Belgian-Dutch expedition. 17 traverses carried including 138 measurements of ice thickness.	Gravimetric measurements	BE
SAE-5859	Inland Plateau - East Antarctica	Soviet Antarctic Expedition (SAE3) seismic survey along a traverse from Mirny to the Pole of Relative Innaccessibility and between Komsomolskaya and Vostok (1958-59). 27 seismic shots made. Traverse distance 2300 km.	Seismic reflection	RU
SAE-5960	Inland Plateau - East Antarctica	Soviet Antarctic Expedition (SAE4) seismic survey along a traverse from Komsomolskaya to Vostok and on to the South Pole (1959-60). 12 seismic shots made. Traverse distance 1832 km.	Seismic reflection	RU
SAE-6364	Inland Plateau - East Antarctica	Soviet Antarctic Expedition (SAE9) seismic survey along a traverse from Vostok to the Pole of Relative Innaccessibility and on to Molodezhnaya (1963-64). 21 seismic shots made. Traverse distance 3323 km.	Seismic reflection	RU
SAE-5658	Queen Mary Land	Soviet Antarctic Expedition (SAE1 & 2) seismic survey along a traverse from Mirny to Pionerskaya (1956-58).	Seismic reflection	RU
SAE-6061	Queen Mary Land, Wilhelm II Land.	Soviet Antarctic Expedition (SAE5) seismic survey along a traverse from a point approximately 100 km north of Pionerskaya south-west for 500 km then south-east to Komsomolskaya (1960-61).	Seismic reflection	RU
MIRNYDOMEC-7886	Wilkes Land	ANARE ground based RES survey in Wilkes Land, 1978-86. Traverse from Mirny to Pionerskaya to Dome C.	Seismic reflection & gravity	AU
NBS-5152	Queen Maud Land	Seismic shooting in Queen Maud Land by Norwegian-British-Swedish Antarctic Expedition, 1951-52. Oversnow traverse inland from Maudheim station.	Seismic reflection	UK
JARE-9294	Dronning Maud Land	JARE 33 (1992-94) oversnow traverse between Mizuho Station and Dome F, Dronning Maud Land.	Ground-based RES	JP
JARE-9597	Queen Maud Land	JARE 37 oversnow traverse in Dome F region. 150 km long traverse from the Dome to the south, and 130 km long traverse from the Dome region to east.	Ground-based RES	JP
SIPLE-97	Siple Coast, Marie Byrd Land	USAP 60 km oversnow traverse at the head of Ice Stream C. Ice thicknesses determined by reflection seismic shooting and the surface elevation by GPS.	Seismic reflection	US

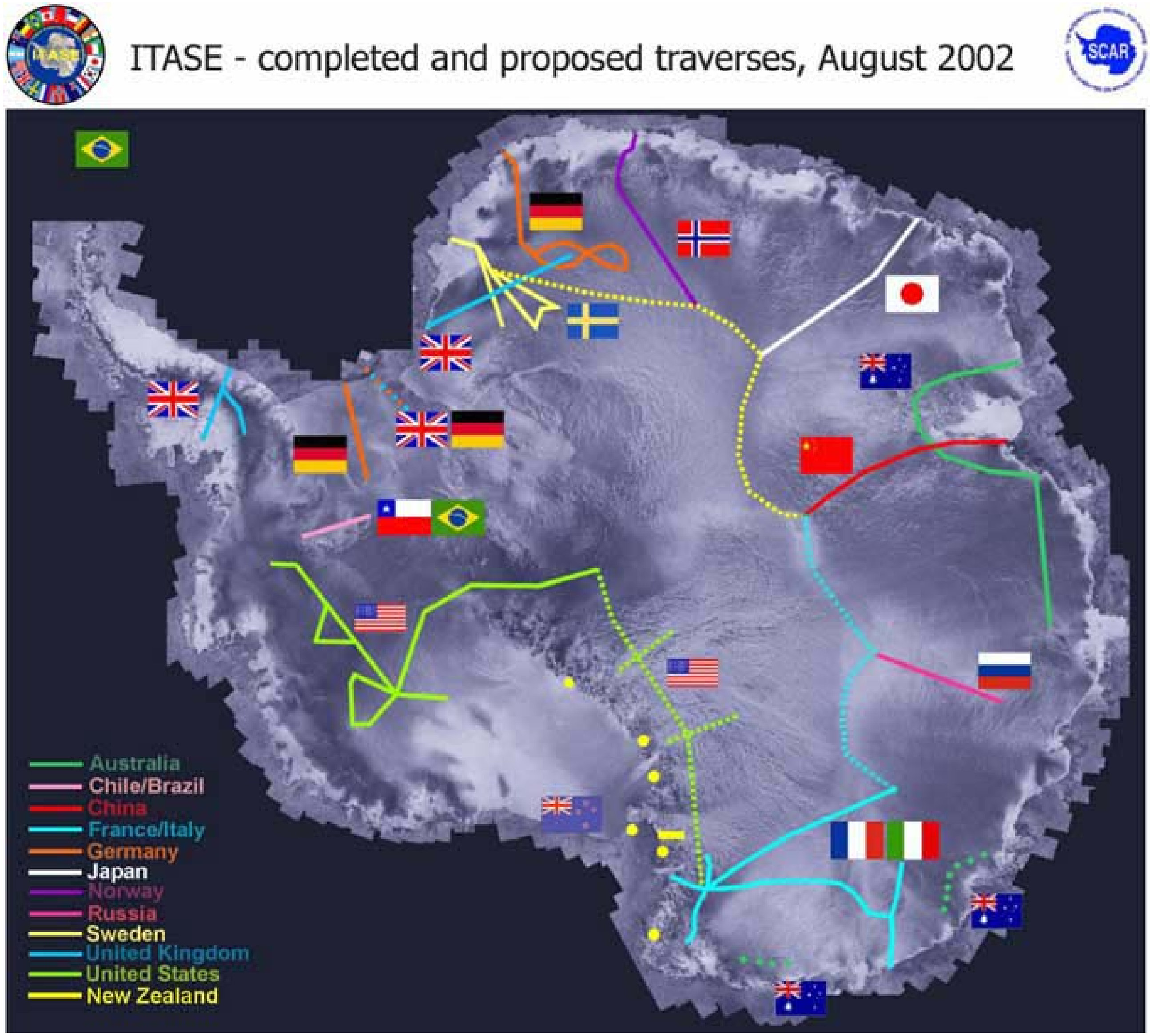
Table 2-2. Summary of Scientific Traverses and Surface-based Surveys in Antarctica

Mission ID	Region	Description	Data Type	Country
LARSEN-90	Larsen Ice Shelf, Antarctic Peninsula	BAS seismic traverse on the Larsen Ice Shelf in the 1990/91 season. Profile length 21.6 km, surface of ice shelf at 34 m above mean sea level.	Seismic reflection	UK
PATRIOT-9798	Patriot Hills, Ellsworth Land	Chilean oversnow RES traverse in the Patriot Hills area conducted under a Chilean Antarctic Institute (INACH) sponsored program. The logistic support was provided by the Chilean Air Force. The data were collected by a radio echo sounding profiling system mounted on sledges and pulled by snowmobiles.	Ground-based RES	CL
ARGEN-8891	Larsen Ice Shelf	Instituto Antartico Argentino (IAA) glaciological and geophysical traverse carried out in two seasons between 1988 and 1991covering about 80 km between Gray Nunatak and Jason Peninsula. nine seismic shots and three RES stations	Seismic reflection & RES	AR
SIPLEDOME-9596	Siple Dome, Siple Coast	US oversnow RES traverse across Siple Dome collected in the 1996/97 season. Sixteen-hundred and ten xy points corresponding to the location of radar waveforms points were derived by interpolation at intervals of ~ 100m from a set of 69 static GPS surveys of markers located along the traverse route.	Ground-based RES	US
	Wilkes Land	The geophysical traverse extended from the Taylor Dome drill site in the Transantarctic Mountains to the center of the Wilkes subglacial basin.	Seismic reflection	US/NZ
	Enderby Land	Japanese Antarctic Research Expedition (JARE) 12 and 13 1972-1973	Glaciology	JP
	Enderby Land	Japanese Antarctic Research Expedition (JARE) 15	Glaciology	JP
	Enderby Land, Queen Maud Land	Syowa-South Pole Traverse 1968-69	Glaciology	JP
	Dronning Maud Land	Norwegian Traverse of 1996-97. EPICA pre-site survey	Glaciology	NW
	Marie Byrd Land	Byrd Station to South Pole Traverse 1960-61	Glaciology	US
LAND BASED SURVEYS				
RUTFORD-8586	Ellsworth Land & Ronne Filchner Ice Shelf	BAS ground based RES of Rutford Ice Stream, 1985/86 season	Ground-based RES	UK
FILCHNER-5758	Filchner Ice Shelf	US seismic soundings carried out in the Filchner Ice Shelf area during 1957-58 (IGY).	Seismic reflection	US
AMERY-6871	Amery Ice Shelf	ANARE Amery Ice Shelf Expedition 1968 and 1970/71. Includes 22 individual traverses.	Ground-based RES	AU
WILKES-7886	Wilkes Land	ANARE ground based RES survey east inland of Casey Station with data at two km spacing.	Ground-based RES	AU
ELLSBYRD-5859	Ellsworth Land	US seismic soundings carried between Ellsworth and Byrd Stations during 1958-59.	Seismic reflection	US
130WEST-5859	Marie Byrd Land	US seismic soundings carried out along meridian 130W in 1958-59	Seismic reflection	US
88WEST-5960	Ellsworth Land	US seismic soundings carried out along meridian 88W in 1959-60.	Seismic reflection	US
RIGGS-7378-1	Ross Ice Shelf	US Ross Ice Shelf Geophysical and Glaciological Survey using seismic and radio wave velocities to determine ice thickness in 1974-1978.	Seismic reflection	US
WALGREEN-6061	Walgreen Coast, Marie Byrd Land	US seismic reflection shooting along the Walgreen coast, Marie Byrd Land in 1960-61.	Seismic reflection	US
ELLSWORTH-6061	Ellsworth Land	US seismic and gravity observations in the Ellsworth Highlands in 1960-61	Seismic reflection & gravity	US
ROOSEVELT-6263	Roosevelt Island, Ross Ice Shelf	US seismic measurements obtained on Roosevelt Island 1962-63	Seismic reflection	US
SAE-7584	Coats Land, Ronne-	Soviet Antarctic Expedition (SAE21-29) seismic reflection surveys carried out in Coats Land	Seismic reflection	RU

Table 2-2. Summary of Scientific Traverses and Surface-based Surveys in Antarctica

Mission ID	Region	Description	Data Type	Country
	Filchner Ice Shelf	and the Ronne-Filchner Ice Shelf between 1974/75 and 1983/84, total area surveyed 583,000 km.		
WISCONSIN-6364	Whitmore Mountains, Marie Byrd Land	US oversnow seismic survey north of Horlick Mountains in Whitmore Mountains in 1963/64.	Seismic reflection	US
BELGE-6768	Jutulstraumen, Western Dronning Maud Land	Gravity survey across the 50 km wide Jutultraumen Ice Stream by the 1967-68 Belgian Antarctic Expedition.	Gravimetric measurements	BE
PENSACOLA-6566	Pensacola Mountains	USGS seismic reflection survey in the Pensacola Mountains during the 1965-66 season.	Seismic reflection	US
SORROND-8692	Sor Rondane Mountains, Dronning Maud Land	Glacier valley cross-section profiles in the central Sor Rondane Mountains gathered by gravimeter and radio-echo sounding measurements during the Japanese Antarctic Research Expeditions JARE-28 and JARE-32.	Ground-based RES & gravimetric	UK
RUTFORD-9193	Rutford Ice Stream, Ellsworth Land	BAS seismic surveys on the Rutford Ice Stream during the 1991-92 and 1992-93 seasons. Surveys were concentrated above the grounding line using three different seismic sources depending on time and resources.	Seismic reflection	UK
DOMEC-9293B	Dome C, Wilkes Land	Italian Antarctic Program (PNRA) ground based RES survey at Dome C, Wilkes Land. Twenty one profiles were carried out from a snocat (rover) in a 50 km x 50 km square grid (line spacing 10 km).	Ground-based RES	IT
WILKES-6163	Wilkes Land	ANARE seismic reflections obtained on route from Wilkes Station to Vostok in 1961/62 and 1962/63 seasons. Data restricted to stations within 300 miles of the coast.	Seismic reflection	AU
ROOSEVELT-9697	Roosevelt Island, Ross Ice Shelf	US ground based radar echo sounding survey on Roosevelt Island undertaken by the Geophysics Dept. University of Washington in the 1996/97 season. Included eight profiles.	Ground-based RES	US
RONNE-8284	Ronne Ice Shelf	BAS geophysical expedition across the Ronne ice Shelf in the 1982/83 and 1983/84 seasons. Three hundred and eighty-four seismic and RES measurements of ice thickness made over 3500 km of ice shelf.	Seismic reflection & RES	UK
ELLSW-PEN-8587	Ellsworth Land & James Ross Island	BAS geophysical expedition in Ellsworth Land and James Ross Island in the 1985/86 and 1986/87 seasons. One hundred and eighty-five seismic and RES measurements of ice thickness made.	Seismic reflection & RES	UK
BERKNER-9899	Ronne Ice Shelf	BAS seismic surveying around the south-west tip of Berkner Island, Ronne Ice Shelf made during the 1998-99 season.	Seismic reflection	UK
SAE-7075	Enderby Land	Soviet Antarctic Expedition (SAE16-20) seismic reflection survey in Enderby Land. Two hundred and ninety stations along the Prince Olaf Coast.	Seismic reflection	RU
SAE-7174-2	Lambert Glacier, Amery Ice Shelf	Soviet Antarctic Expedition seismic surveys - East Antarctica (1970/71 - 1983/84).	Seismic reflection	RU
KGI-9597	King George Island	Russian-Brazilian ground-based RES in December 1995 and December 1996-January 1997 using a monopulse radar with acentral frequency 40 MHz and GPS for navigation. Radar data were recorded on film using an oscilloscope C1-73 and a photo camera.	Ground-based RES	RU

Figure 2-5. International Trans Antarctic Scientific Expedition (ITASE) Traverses



3.0 ALTERNATIVES

3.1 Introduction

Several options were analyzed for the development and implementation of USAP surface traverse capabilities. Additionally, the option of "no action" or maintaining the status quo, is discussed here as are several alternatives that were identified but not considered and thus eliminated from detailed analysis.

The primary goal of the proposed action is to develop surface traverse resources that could be used in conjunction with existing USAP airlift capabilities to re-supply USAP facilities and provide a platform for scientific research or advanced surface-based survey activities in Antarctica. Each year, logistical support is needed to re-supply existing facilities, establish or decommission temporary scientific field camps, or provide other specialized support to scientific research at numerous field sites. Because surface traverse and airlift transport mechanisms offer different advantages, they are both expected to serve as essential components in meeting the annual logistical support needs and research requirements of the USAP. The use of surface traverse mechanisms in conjunction with airlift support will provide a number of additional benefits including reduced reliance on aircraft resources, increased opportunities to expand science at USAP facilities (including the South Pole), and resource savings (the example logistics traverse presented here shows as much as a 40% reduction in fuel usage compared to aircraft deliveries of materials to South Pole).

In order to evaluate potential environmental impacts associated with surface traverses used for re-supply missions for this CEE, a surface traverse route between McMurdo Station and the South Pole was selected as the first example. An analysis of the specific operating characteristics (e.g., route, transport configuration) for an optimally configured re-supply traverse to the Amundsen-Scott South Pole Station is presented in Appendix A. Based on the finite quantity of airlift available to support the Amundsen-Scott Station, and the expanding scientific endeavors pursued at the geographic South Pole, the development of a surface traverse capability for re-supply missions is a priority for the USAP.

To evaluate potential impacts associated with scientific traverses and surface-based surveys, the International Trans Antarctic Scientific Expedition (ITASE) traverse conducted by the USAP was selected as a representative example, although future scientific traverses will be customized to meet the specific objectives of the intended research. Appendix B provides a detailed description of a recent ITASE traverse mission.

Sections 3.2 through 3.7 identify various alternatives considered in this CEE for the operation of surface traverses for re-supply (Table 3-1). This exercise is straightforward to accomplish for the first example of a logistics traverse (between McMurdo Station and the South Pole). However, because the technical scope of future research proposals may be specifically designed to employ the use of science-related traverse activities or surface-based surveys, there are no relevant alternatives for science traverses, other than performing the research as proposed or not doing it at all. Therefore, the only science-related traverse alternative under consideration is Alternative A, that is conducting the traverse under the optimal conditions described in the experimental design of the research proposal. Section 3.8 describes alternatives that were identified but were not analyzed.

Table 3-1. Alternative Actions Considered in this Evaluation

Alternative	Description
A	Optimally Configured Condition

Table 3-1. Alternative Actions Considered in this Evaluation

Alternative	Description
B	Minimum Frequency Condition
C	Reduced Intensity Condition
D	Minimal Field Support Condition
E	Use of Existing Routes Condition
F	No Action Condition (Status Quo)

3.2 Alternative A – Develop Traverse Capability and Implement Under Optimal Configuration Conditions (Preferred Alternative)

Re-supply Traverses

In this alternative, surface traverse capabilities would be developed to provide logistical support to selected USAP facilities by configuring the components and operation of the traverse to achieve maximum efficiency when used in combination with airlift support. An optimally configured re-supply traverse will provide a practical balance between surface transport and airlift depending upon the specific types of cargo to be transported. To achieve this balance, the traverse route, the timing and frequency of each traverse, and the configuration of the transport equipment, will be customized to suit the cargo transport needs. It is expected that optimally configured re-supply traverses will be conducted on a relatively routine basis (several roundtrips per austral summer) using appropriately designed and sized equipment over improved and marked (e.g., GPS coordinates, flagged) routes.

In order to identify and evaluate potential environmental and operational impacts, the design characteristics and specifications were reviewed for the use of an optimally configured re-supply traverse transport mechanism to the South Pole (Appendix A). Using the conditions described in this study, an optimally configured re-supply traverse (Alternative A) would consist of a convoy of tractors towing cargo sleds from McMurdo Station to the Amundsen-Scott Station several times each austral summer season (Table 3-2). For the South Pole re-supply scenario, each 3,200 km roundtrip (or swing) would require approximately 30 days to complete and would occur during the South Pole's austral summer operating season, typically from late October to mid-February.

Table 3-2. Estimated Statistics for an Optimally Configured Surface Re-supply Traverse from McMurdo Station to the Amundsen-Scott Station (Alternative A)

Number of Swings per Season (i.e., year)	Number of Tractors Towing Cargo Sleds per Swing	Cargo Delivered per Swing [per year] (kg)	Volume of Fuel Consumed for Traverse (liters per year)
6	6	133,000 [800,000]	750,000

The specifics of other optimally configured re-supply traverses will depend upon the destination, the type and quantity of cargo to be transported, and the desired or necessary route. Routes which traverse areas where environmental conditions are substantially different than those evaluated in this CEE (i.e., Ross Ice Shelf, Transantarctic Mountains, Polar Plateau) would require supplemental environmental review.

An optimally configured traverse may require the temporary storage of fuel or cargo at designated areas along the traverse route for use by the swing on the return leg of the trip. For the McMurdo to South Pole re-supply traverse example, a portion of the fuel for the traverse vehicles would be temporarily stored at one or more caches along the route. Alternatively, fuel could be deposited at these caches by airdrops. To facilitate redeployment for subsequent swings, it is expected that traverse equipment will be returned to a supporting station or outlying facility. Supplies temporarily staged or cached in the field would typically be recovered at the end of each summer season and returned to the supporting station. However, in some cases, it may be practical to leave selected equipment or caches in the field over the austral winter using established procedures to ensure their recovery and prevent the release of these materials to the environment (reference 1). In addition, a traverse route may require periodic maintenance (e.g., surface grooming, crevasse detection and mitigation) either by a swing or a support team to ensure safe traverse operations.

Scientific Traverses

The proposed USAP surface traverse capability may be used as a platform for in-field scientific research activities. An optimally configured (Alternative A) research traverse would be based on the types of research to be conducted, the number of personnel performing the research, and the duration and routing of the traverse. To enhance mobility and efficiency, fuel or other supplies may be temporarily cached in the field either by airdrops, delivery by aircraft, or separate re-supply traverses. Optimally configured surface-based surveys as well as science traverses will typically be conducted along one or more specific routes using equipment designed and configured for the intended research. It is expected that traverses used for science applications would typically follow undeveloped routes in the areas intended for the research but may also use routes established for re-supply purposes, if available.

The 2002-2003 International Trans Antarctic Scientific Expedition (ITASE) traverse conducted by the USAP (Appendix B) is an example of an optimally configured traverse used for research purposes. This traverse was one in a series of multinational research traverses conducted on the Polar Plateau. The 2002-2003 ITASE traverse covered the 1,250 km distance between Byrd Field Camp and the South Pole in 40 days while performing glaciological and atmospheric research at eight designated sites. The 2002-2003 ITASE traverse proceeded on an undeveloped route using two tractors towing 10 trailers and staffed by 13 scientists and support personnel. To optimize efficiency, the ITASE utilized a series of fuel caches placed at strategic locations along the traverse route.

3.3 Alternative B – Develop Surface Traverse Capability and Implement Under Minimum Frequency Conditions

Re-supply Traverses

In this alternative, surface re-supply traverses would be configured similar to those described in Alternative A but each individual traverse would occur on a less frequent basis each austral summer season. Using the McMurdo Station to South Pole re-supply mission as an example, Table 3-3 summarizes the details of the use of three surface traverses per year as opposed to the optimum number of six.

Table 3-3. Estimated Statistics for a Surface Re-supply Traverse to the Amundsen-Scott Station from McMurdo Station Operating Under Minimal Frequency Conditions (Alternative B)

Number of Swings per Season (i.e., year)	Number of Tractors Towing Cargo Sleds per Swing	Cargo Delivered per Swing [per year] (kg)	Volume of Fuel Consumed for Traverse (liters per year)
3	6	133,000 [400,000]	375,000

Scientific Traverses

Reducing the frequency of science-related traverses on a project or annual basis may severely compromise the quality of the intended research and therefore may not be feasible. No further analysis will be pursued in this CEE pertaining to the reduction in the frequency of scientific research traverses.

3.4 Alternative C – Develop Surface Traverse Capability and Implement Under Reduced Intensity Conditions

Re-supply Traverses

In this alternative, surface re-supply traverses would transport cargo on the same frequency as described in Alternative A but would use only three tractors per swing instead of the six if optimally configured. Based on the McMurdo Station to South Pole re-supply mission as an example, Table 3-4 summarizes the details associated with this operating configuration.

Table 3-4. Estimated Statistics for a Surface Re-supply Traverse to the Amundsen-Scott Station from McMurdo Station Operating Under Reduced Intensity Conditions (Alternative C)

Number of Swings per Season (i.e., year)	Number of Tractors Towing Cargo Sleds per Swing	Cargo Delivered per Swing [per year] (kg)	Volume of Fuel Consumed for Traverse (liters per year)
6	3	67,000 [400,000]	375,000

Scientific Traverses

The configuration of science-related traverses (number and size of science-related cargo modules and tractors) would be based on the experimental design of the intended research. Reducing the number of tractors or cargo modules for research traverses may severely compromise the quality of the research and therefore may not be feasible. No further analysis will be pursued in this CEE pertaining to the reduction of resources for scientific research traverses.

3.5 Alternative D – Develop Surface Traverse Capabilities and Implement Using Minimal Field Support Resources

Re-supply Traverses

Alternatives A, B, and C will likely involve the use of field caches, depots, or camps to optimize the effective cargo carrying capacity of the re-supply traverse. For example, fuel intended to be consumed on the return leg of the mission, or empty fuel containers or wastes, may be temporarily stored along the traverse route for subsequent pickup on the return to the base station. If field caches, depots, or camps are not used for this purpose, the useful load (i.e., quantity of deliverable cargo) may be reduced. Using the McMurdo Station to South Pole re-supply mission as an example, Table 3-5 summarizes the conditions if no intermediate storage facilities are used. In this example, the quantity of cargo delivered would be reduced by four percent.

Table 3-5. Details of a Surface Re-supply Traverse to the Amundsen-Scott Station from McMurdo Station Operating With Minimal Field Support (Alternative D)

Number of Swings per Season (i.e., year)	Number of Tractors Towing Cargo Sleds per Swing	Cargo Delivered per Swing [per year] (kg)	Volume of Fuel Consumed for Traverse (liters per year)
6	6	128,000 [768,000]	750,000

Scientific Traverses

Research-related traverses could function without the use of field caches, depots, or camps but this could adversely affect the efficiency of the mission. For example, the tractors towing the science and personnel support equipment could transport all of the fuel and other supplies needed for the entire mission from the onset but this would essentially result in the transport of dead weight for a portion of the trip, especially an out-and-back route. Alternatively, fuel or other supplies could be airlifted to the traverse team in the field on an as-needed basis but this would require precise planning and coordination of resources which could easily be compromised by adverse weather or mechanical problems. As a result, the elimination of the use of field caches, depots, or camps by scientific traverses is not a practical alternative and will not be analyzed further in this CEE.

3.6 Alternative E – Develop Surface Traverse Capabilities and Implement Using Existing Routes Only

Re-supply Traverses

In this alternative, the USAP would develop and conduct optimally configured re-supply traverses as described in Alternative A but would only utilize existing routes in Antarctica. Assuming that the ongoing proof of concept traverse evaluation is successfully completed by 2007, the only USAP surface traverse route available will be from McMurdo Station to the Amundsen-Scott Station via the Ross Sea Ice Shelf and the Leverett Glacier. Table 3-2 summarizes the details of an optimally configured re-supply traverse which would exclusively use this route to the South Pole.

Scientific Traverses

Theoretically scientific traverses could be limited to established traverse routes in Antarctica either maintained by the USAP or other nations but this restriction could severely inhibit research opportunities on the continent. As a result, no further analysis on restricting the routes of scientific research traverses will be pursued.

3.7 Alternative F – Do Not Develop Surface Traverse Capability and Continue to Use Air Support Only (No Action Alternative)

The no action alternative suggests that the USAP would not develop surface traverse capabilities and aircraft would continue to be used exclusively as the primary logistical transport mechanism providing support to selected USAP facilities and research sites. Traverses for science-related research would either be curtailed completely or would require separate environmental reviews on a case-by-case basis.

3.8 Alternatives Identified But Not Analyzed

Several additional alternatives were identified but were eliminated from further consideration in this CEE due to technical reasons. The following alternatives included variations on the traverse location, equipment, and operational characteristics.

3.8.1 Surface Re-supply Traverse to the South Pole from Dumont d'Urville via Concordia Station

The French and Italians have jointly developed and are currently operating a surface traverse capability to transport supplies from a coastal facility at Cape Prudhomme (near Dumont d'Urville) to the Dome C Station (Concordia) on the Polar Plateau. As an alternative for the re-supply of the Amundsen-Scott Station, the USAP could potentially use this existing traverse route to Concordia and develop a new route from Concordia to the South Pole. Implementation of this alternative would involve transporting supplies to Cape Prudhomme by vessel, offloading and temporarily storing the materials for subsequent transport by traverse to the South Pole. Neither Cape Prudhomme nor Dumont d'Urville currently has the infrastructure to support this type of operation without substantial expansion. Additionally, the "Dome C" route is twice the overall distance of the "Leverett" route, resulting in a much higher environmental exposure as well as cost per kilogram delivered. For these reasons this alternative was eliminated from further consideration.

3.8.2 Develop and Implement Surface Traverse Capability Using Low Exhaust Gas Emission Equipment

The types of equipment proposed for use on re-supply or scientific traverse missions (e.g., Caterpillar Challenger models 55 and 95; Case Quadtrac STX450) are currently used in the USAP (and in other national Antarctic programs) for various field and station operations. These vehicles have been shown to be suitable for these types of applications and operate reliably under polar conditions. The USAP has a substantial number of trained mechanics and parts inventories needed to support and maintain these types of vehicles. Consistent with the acquisition practices for the existing fleet of USAP vehicles, tractors procured for surface traverse uses would be acquired in the United States and built to meet U.S. emissions standards which are increasingly stringent for construction and off-road vehicles. Although vehicles with lower exhaust gas emissions may be potentially available, equipment which is underpowered or has not been proven to operate reliably and effectively under polar conditions could jeopardize safety and the completion of the mission. As a result, the equipment described in this CEE represents the optimum combination of functionality for the intended application and fuel combustion efficiency. Potential environmental benefits derived from the selection of other types of equipment were deemed to be negligible and were eliminated from further consideration in the CEE.

3.8.3 Minimize the Transport of Fuel

Each year, the USAP transports a considerable volume of petroleum hydrocarbon fuels, principally diesel fuel (JP-8, AN-8) to remote locations for use in generators, heating devices, heavy equipment, and vehicles. Nearly all of this fuel is currently transported by aircraft. Fuel represents a commodity which has a significant potential to adversely impact the environment because it is a liquid and under certain conditions may migrate (i.e., diffuse, disperse) in the environment. The risk of adverse environmental impacts caused by fuel spills or related releases can be reduced by several means, including minimizing the quantity of fuel transported into the field either by surface traverse or aircraft.

Fuel is essential for the operation of all USAP facilities. Using the equipment and procedures described in the CEE, fuel transport by surface traverse is expected to be as secure as transport by aircraft. Use of the surface traverse capability for fuel as well as other supplies would provide the USAP with the ability to optimize a combination of transport mechanisms to efficiently suit the specific needs of the mission and resources available. Since minimization of the amount of fuel transported by surface transport would not reduce potential environmental hazards (while at the same time reducing the ability to optimize transport mechanisms), this alternative has been eliminated from further consideration.

4.0 DESCRIPTION OF PROPOSED ACTIVITES

4.1 Introduction

The proposed activities associated with the development and implementation of surface traverse capabilities for both re-supply and scientific research applications in the USAP are discussed here. The purpose and need for the proposed action is presented in Section 4.2 and includes a description of the goals and benefits of potential traverses. Section 4.3 provides a description of the typical components of a surface traverse including the route, resources (e.g., personnel, equipment), operating factors (e.g., loads, schedules), field logistical support, and off-season activities. Finally, Section 4.4 contains a detailed description of the nature and intensity of anticipated traverse activities.

Whether the proposed surface traverse is for re-supply or scientific research (while the purpose and scale may be significantly different), both types of surface traverses will involve the use of multiple motorized tracked vehicles towing sleds or trailers containing living and working modules for the traverse crew, fuel for the traverse equipment, as well as payload or cargo. The scope of a traverse performed by the USAP will be dependent of the specific needs of the mission and cannot be definitively stated in this CEE. However, examples of re-supply and science traverses have been presented in order to identify and evaluate potential environmental and operational impacts. The example of a re-supply traverse was recently the subject of a proof of concept study (Appendix A) and involves the transport of fuel and other cargo to the Amundsen-Scott Station from McMurdo Station. The 2002-2003 USAP ITASE traverse is part of a multi-year research effort by several nations and was used as an example to characterize the potential environmental and operational impacts associated with this type of traverse activity. A technical description of the recent ITASE traverse is provided in the activity's end-of-season report (Appendix B).

4.2 Purpose and Need

In support of the United States Antarctic Program (USAP), the National Science Foundation (NSF) proposes to develop and implement enhanced surface traverse capabilities in Antarctica. The successful development and use of surface traverses will enable the USAP to meet several logistical and scientific goals.

The primary purpose of developing a surface traverse capability will be to enhance the USAP's current logistical support mechanism for the re-supply of facilities in Antarctica, specifically to provide a more capable alternate transportation method to complement the existing airlift resources. The development and use of surface traverse resources would allow logistical planners to optimize the transportation of fuel, cargo, and supplies to various USAP facilities through the implementation of a combination of airlift and surface traverse mechanisms as conditions warrant. The surface traverse capability would also allow the USAP to efficiently transport cargo to locations where airlift may not be possible or practical.

An equally important purpose for the development of a surface traverse capability relates to the use of the traverse as a platform to perform advanced surface-based scientific studies in Antarctica. Recent traverse activities conducted by the USAP as a partner in the International Trans Antarctic Scientific Expedition (ITASE) demonstrate the value of surface-based scientific research supported by mobile facilities.

The need to develop and implement surface traverse capabilities hinges on limitations inherent to the USAP's heavy reliance on the existing airlift support mechanism. The current airlift support system has a limited number of aircraft, crews, and suitable operating days available each year. As a result, the airlift system typically operates near capacity levels each year with little flexibility or opportunity for expansion. Most of the USAP's heavy-lift, long-range airlift capability is provided by ski-equipped LC-130 Hercules aircraft.

The Amundsen-Scott Station is approximately 1,600 km from McMurdo Station and is supported exclusively by LC-130 aircraft. Each LC-130 flight has the capacity to deliver up to 11,800 kg of cargo and personnel to the South Pole. Much of the available LC-130 airlift capacity for the entire field season is consumed by re-supply of Amundsen-Scott Station, in particular, the delivery of fuel. When delivering fuel the LC-130 actually consumes more fuel with each trip than it deposits at the station. Using the example re-supply traverse, compared to a single aircraft, each tractor would deliver to South Pole significantly more material (approximately twice as much) per roundtrip for approximately the same amount of consumed fuel. The delivery of fuel and other cargo to the South Pole represents a significant use of the limited aircraft resources, particularly when rapid delivery of these re-supply materials is often unnecessary.

Because surface traverse and airlift transport mechanisms each offer different advantages, they are both expected to serve as essential components in meeting logistical and scientific goals of the USAP depending upon the specific needs of the mission and environmental conditions. The following provides additional details regarding the purpose and need for the USAP to develop and implement a robust surface traverse capability.

4.2.1 Description of Current Air Logistical Support Systems

Each year the USAP operates numerous aircraft within Antarctica for logistical support and direct support of scientific research activities. Available aircraft operated within Antarctica by the USAP include ski-equipped LC-130 Hercules for heavyweight and bulky cargo missions as well as ski-equipped Dehaviland Twin Otters. Helicopters are also operated, and are primarily assigned missions in the McMurdo area and the Dry Valleys. All of these aircraft are flown only during the austral summer operating season, typically from October through February.

In general, larger field camps that are used as bases for scientific research activities are established at snow-covered locations which can be safely accessed by ski-equipped aircraft. Smaller field camps (i.e., tent camps) or research sites may be supported by aircraft or surface vehicles, typically small tracked vehicles (e.g., LMC Spryte, Kassbohrer Pisten Bully, snowmobiles) operating from a supporting station or base camp. In addition, some field efforts are periodically resupplied by LC-130 aircraft via airdrops at strategic locations.

For the past several years, the USAP has operated an average of 400 intra-continental LC-130 missions per year, including 280 missions to the Amundsen-Scott Station at the South Pole and 120 missions to support various other field locations, in total representing approximately 3,000 flight hours. Twin Otters typically provide 1,000 hours (or 200 missions) of flight support annually to numerous snow-covered sites, while helicopters generally provide 1,500 hours of flight support primarily in the McMurdo area and locations in the Dry Valleys.

The LC-130 aircraft is the largest ski-equipped aircraft available to the USAP and is the only resource used to annually re-supply the Amundsen-Scott Station. The LC-130 aircraft also provide logistical support to other USAP facilities and science projects at various locations within Antarctica. This support is typically provided to 10 locations annually, including the re-supply of selected field camps and research sites (e.g. Automatic Geophysical Observatories, Long Duration Balloon recovery) and may include the delivery and pickup of personnel, supplies, equipment, and fuel. In addition, LC-130 aircraft routinely airdrop drums of fuel or other supplies to selected locations depending upon the needs of various research or operational projects. Twin Otter aircraft also provide logistical and science support to numerous locations in the field. Because of the Twin Otters' limited transport capacity as compared to the LC-130, the Twin Otter's primary focus is to support smaller facilities or perform various types of aerial monitoring.

4.2.2 Limitations of Air Logistical Support

The USAP's airlift logistical support system is subject to various constraints including operating periods, cargo transport dimensions and capacities, environmental conditions, and personnel (e.g., flight crew, ground support) limitations. The safe load capacity of the LC-130 aircraft is limited to 103 m^3 of cargo space (12.3 m long, 3.1 m wide, 2.7 m high) and 11,800 kg which may include 14,500 liters of fuel stored in the wing tanks of the aircraft.

The annual re-supply of the Amundsen-Scott Station may include the transport of scientific instruments, construction materials, heavy equipment, and station operating supplies. Currently, transport of these materials is subject to the cargo size and weight restrictions of the LC-130 aircraft. Building components used for the ongoing reconstruction of the station were designed to be modular and sized to fit within the LC-130 aircraft. Equipment shipped to the South Pole for scientific research projects must also be designed and configured to fit within the aircraft's size limitations. For example, the equipment needed for the proposed neutrino telescope of Project IceCube or the eight-meter telescope, must be disassembled into units which can be accommodated on the LC-130 aircraft.

Based on recent history, it is estimated that the current fleet of LC-130 aircraft available to the USAP could potentially fly slightly more than 400 missions during an austral summer season but inevitable delays or postponements due to weather or other factors usually lower this number. Because the Amundsen-Scott Station is solely dependent on the LC-130 aircraft for re-supply, a major portion of the available LC-130 resources must be allocated for this purpose. The remaining LC-130 resources available each austral summer season may be used for other scientific support missions but often the demand for these resources exceeds the capacity. As a result, the availability of LC-130 resources can potentially limit the start of new science projects in Antarctica, both at South Pole and elsewhere on the continent.

The majority of LC-130 airlift capacity to the South Pole each year is used to deliver fuel, a vital commodity for the continued safe operation of the Station. The four-engine LC-130 aircraft consumes more fuel in a roundtrip to the South Pole from McMurdo Station (approximately 17,200 liters) than can be delivered (approximately 14,500 liters). Periodically, planned flights to the South Pole may be delayed due to adverse weather, extreme temperatures, or other unexpected conditions (aircraft maintenance). Delayed flights must be made up in order to deliver the minimum quantity of fuel and other materials needed to sustain operations at South Pole, particularly over the inaccessible 250-day austral winter. Although the LC-130 aircraft have always been able to deliver the fuel needed for USAP operations at the South Pole, other types of cargo or missions to other locations have at times been compromised because no alternate transport methods are currently available to re-supply the Amundsen-Scott Station.

4.2.3 Benefits of Surface Traverses

The development and use of a surface traverse capability by the USAP will provide an alternate and viable means to provide logistical support to USAP facilities and scientific research efforts which is not subject to the physical limitations of aircraft. In addition, since the USAP does not currently have a robust traverse capability, new science projects involving mobile surface-based research could be performed using equipment optimally configured for this purpose as opposed to airlift support or traverse capabilities patched together using existing resources. While the proposed development and use of traverse capabilities in the USAP is not intended to replace the existing aircraft logistical support system, it will supplement current airlift resources and allow the benefits of each transport mechanism to be effectively realized.

4.2.3.1 Increased Reliability

The use of surface traverses as part of a diversified logistical support system will provide the USAP with a greater level of reliability than is currently provided with the exclusive use of aircraft. Because a variety of environmental conditions (e.g., wind, snow, extremely low temperatures) may affect the safe operation of aircraft, flights are often delayed or cancelled when adverse weather conditions are encountered at the point of origin, destination, or locations enroute. Because the safe operation of surface traverse equipment is more tolerant of adverse weather conditions than aircraft, traverse activities can be scheduled with a reduced level of risk of significant delay or cancellation. Having a dual mode capacity to make deliveries to the interior of Antarctica greatly reduces the risks posed by a single-point failure in the current system.

4.2.3.2 Resource Savings

The use of surface traverse capabilities in conjunction with airlift support will result in resource savings to the USAP, including fuel, personnel time, and associated support services. Using the South Pole re-supply traverse as an example, it is expected that each tractor towing cargo trailers will be capable of delivering approximately twice the amount of cargo to the South Pole as a single LC-130 aircraft while consuming close to the same amount of fuel. Specifically, for each 100,000 kg of cargo transported to the South Pole from McMurdo Station, traverse equipment would consume approximately 90,000 liters of fuel. Transporting the same quantity of cargo by LC-130 aircraft would require 8.5 flights and consume 150,000 liters of fuel. Although aircraft can transport cargo much more rapidly than traverse, transport by traverse could save fuel.

A surface traverse from the South Pole may also be used to transport wastes generated at the Amundsen-Scott Station back to McMurdo Station for subsequent retrograde and disposition in the United States. Wastes expected to be produced at the South Pole in the near future include heavy bulky debris resulting from the demolition of the old station during the South Pole Station Modernization (SPSM) project. The use of the traverse capability for this application will reduce resources required to dismantle larger components and specially prepare the waste for shipment in LC-130 aircraft. In addition, the use of traverse capabilities to transport supplies or wastes will free-up the resources typically used at Amundsen-Scott and McMurdo Station to handle cargo since this function would be performed by the traverse crew.

4.2.3.3 Reduced Reliance on Aircraft Resources

The development and use of traverse capabilities would reduce the reliance on aircraft resources in the USAP by reducing the number of missions and associated flight hours that must be dedicated to re-supply or scientific support missions. There are a finite number of aircraft and crews available to provide support to locations within the Antarctic continent and these resources are typically operated near capacity.

Supplementing the USAP's airlift resources with a traverse capability could eliminate approximately 8.5 flight missions for each 100,000 kg of cargo delivered either allowing a reduction in the number of missions flown or the reprogramming of LC-130 resources for other applications.

4.2.3.4 Increased Opportunities to Perform Scientific Studies in Antarctica

The availability of surface traverse resources will allow the USAP to reliably support a variety of scientific research projects throughout the Antarctic continent including surface-based surveys. Surface-based data collected in strategic areas of Antarctica can be used to document the spatial and temporal variability of glacial, geological, climatological, and atmospheric characteristics which have been traditionally available only from remote sensing sources (e.g., Radarsat, Landsat, Department of Defense imagery). The scientific community has already expressed an interest in conducting such research in Antarctica (reference 2).

The USAP has been able to support various scientific surface-based surveys or traverse research projects in the past using existing USAP resources. Although these missions have been generally successful, the research activities were often performed using equipment or expertise that was not optimized for the specific application and may have potentially complicated the work that was done. The development of the proposed traverse capability will ensure that the USAP has adequate resources and experience available to efficiently support future surface-based research projects.

4.2.3.5 Increased Opportunities to Expand the Scope of Science at the South Pole

In conjunction with the USAP's existing airlift resources, the availability of a surface traverse capability to the South Pole will provide the opportunity to expand the scope of new scientific research projects that may be conducted at the Amundsen-Scott Station. Currently, all science projects at the South Pole are performed using equipment and facilities transported to the Station on LC-130 aircraft. All cargo must conform to the size and weight restrictions of the aircraft. Potential use of a surface traverse capability will expand the types of cargo that can be transported.

4.2.3.6 Increased Opportunities to Provide Logistical Support to Science at Other Field Locations

In conjunction with the USAP's existing airlift resources, the availability of a surface traverse capability would provide the USAP with the flexibility to select the most efficient transport mechanism available to support scientific research projects at remote field locations. Currently, larger field camps are typically established only at locations which can be safely accessed by available aircraft (LC-130, Twin Otters), while smaller field camps are serviced by helicopters or tracked vehicles (e.g., Tucker Snocat, LMC Spryte, Kassbohrer Pisten Bully, snowmobiles). Based on the specific needs of each new research project, a surface traverse capability may provide a more efficient mechanism to transport needed materials and support science.

4.3 Description of Surface Traverses for Re-supply

It is assumed that a re-supply traverse would generally be conducted between two primary facilities (e.g., stations), perhaps with intermediate stops, would follow an established, marked and improved route (e.g., crevasses mitigated, trail groomed), and would be used more than once. Re-supply traverse activities would include equipment, personnel, operating factors, and field logistics. These traverse characteristics would be customized to meet the specific goals of the traverse.

A detailed engineering evaluation of various characteristics composing a re-supply traverse from McMurdo Station to the South Pole has been completed (Appendix A), and is used as an example of a re-supply traverse in this CEE to identify potential impacts. Using this example, the following summarizes the optimum characteristics of a re-supply traverse.

4.3.1 Traverse Route

In general, it is expected that a route used for re-supply missions would be developed so that the path could be safely and reliably reused on a periodic basis. The development of this type of route could involve the mitigation of crevasse hazards by filling them , the marking of the trail, and the establishment of caches or temporary storage and rest areas. Re-supply traverse routes could also involve the use of established paths developed to different destinations.

A proof of concept study is currently being performed to evaluate a possible traverse route between McMurdo and Amundsen-Scott Stations. The proof of concept route, if deemed successful, is divided into four distinct areas: 1) the "shear zone" between the McMurdo Ice Shelf and Ross Ice Shelf, 2) the Ross Ice Shelf, 3) the Leverett Glacier, and 4) the Polar Plateau. The proof of concept route crosses ice and snow areas but does not intersect dry land, seasonal sea ice (marine), wildlife areas, or Antarctic Specially Protected Areas (ASPA). Potential traverse routes, which would cross environmental settings different than those described in this CEE, would require supplemental environmental review.

To ensure safe operations, each surface traverse route is typically inspected for crevasse hazards using remote sensing (aerial or satellite imagery), ground penetrating radar (GPR), or infrared photography. If crevasses are detected, they are either avoided by rerouting around the area or mitigated by filling them with native snow and ice. Crevasses are mitigated by removing surface snow bridges, sometimes with explosives, filling the void with snow and ice, and constructing a stable path sufficiently wide enough to support the traverse equipment. When a crevasse has been successfully avoided or mitigated, the path is groomed and flagged to mark the safe route. Periodically, traverse routes may require maintenance such as the removal of drifting snow, re-grooming, and re-flagging.

4.3.2 Resources

The resources needed to conduct a surface re-supply traverse include equipment, personnel, support facilities and services, fuel, and supplies. The magnitude of resources utilized for each alternative may alter or impact the effectiveness of traverse operations as well as the nature and extent of environmental impacts.

Equipment

The equipment that will be used in a re-supply traverse will comprise, in general, a convoy of tractors towing a series of trailers. The type of tractors to be used on a traverse would be based on the requirements of the mission but each must be able to tow fully laden sleds in a low-traction environment. If the route for a particular traverse has not been fully developed and marked, it is expected that a traverse team would be equipped with GPR crevasse detection equipment and trail maintenance equipment such as groomers or land planes.

The ongoing proof of concept evaluation of a surface re-supply traverse capability between McMurdo and Amundsen-Scott Stations is currently assessing the effectiveness of several types of tractors, including the Caterpillar Challenger 95 and the Case Quadtrac STX450. It is estimated that either of these rubber-track agricultural tractors could leave McMurdo Station towing trailers with a total payload (gross load less tare weights) of about 43,000 kg and deliver in excess of 20,000 kg of cargo to the South Pole.

Each trailer on an optimally configured traverse would be specifically designed to accommodate the types of cargo such as fuel in tanks, cargo in intermodal containers, and bulk cargo. To reduce unnecessary tare weight, the trailers would have a skeletal design allowing secure transport of both modular and loose loads. Modular loads would include intermodal cargo containers that would serve as support facilities for traverse personnel.

Trailers used to transport fuel will be constructed to minimize the height of the trailer's center of gravity and allow modular or loose loads to be placed on the trailer as well. Fuel tanks and other hazardous material containers would be constructed with materials suitable to protect the contents against handling and transportation stresses. Fuel tanks would be equipped with secondary containment or equivalent leak protection measures.

The use of slaved or remote control technology may also be a feasible option whereby the lead tractor would be driven by an operator with the one or more of the remaining tractors unmanned and linked electronically.

Personnel

Skilled personnel will be needed to operate the tractors and support traverse activities including equipment preventive maintenance and refueling. The number of people operating a traverse swing would depend on the specific needs of the mission such as the loads to be transported, the number of tractors, or the distance. It is assumed that a re-supply traverse may be staffed at a ratio of one person per tractor, with additional support camp operational skills supplemented by available or additional staff. It is assumed that some of the traverse equipment operators would be skilled mechanics to handle preventive maintenance and emergency breakdown situations. In addition, some traverse personnel will possess other contingency skills such as emergency first aid, life-saving, mountaineering, communications expertise, and spill response training.

Personnel Support Modules

Each re-supply traverse swing would include the necessary support modules containing facilities needed for the duration of the traverse. For example, one unit would serve as the primary living module with berthing, food preparation and dining areas. A second, back-up living module would be physically separated from the primary unit to minimize the risk of the loss of both in a single mishap. The primary and backup living modules would be capable of berthing and feeding the entire swing team and would contain redundant sets of communications equipment. The back-up module would have its own electrical power generator and a snow melter for production of potable water. A third utilities module would contain the primary power plant (approximately 30kW), potable water generation facilities, sanitary facility (i.e., bathroom), and workshop area. A supplies and spare parts module may also be required.

Fuel and Supplies

Each series of tractors and trailers deployed on a roundtrip mission would be called a swing and would be self-sufficient. Each swing would carry the supplies needed to operate the traverse, including food, fuel, lubricants, maintenance supplies, and waste containers. Cargo containers would be compatible with their contents and structurally able to withstand the physical and environmental conditions encountered during the traverse. Food stores and critical medical supplies would be divided between two berthing modules to minimize the loss of all supplies in the event of a mishap. Other supplies that would be needed for the traverse equipment or maintenance activities such as gasoline, lubricants, and coolants would be transported and stored in containers supplied by the manufacturer or in 208-liter (55-gal) drums. Each swing would also be equipped with the containers needed to collect and manage all wastes generated during the traverse, including solid wastes, sanitary wastes (e.g., human solid waste, urine, greywater), and hazardous wastes, which will be returned to McMurdo for proper processing and disposal.

Support Facilities and Services

During each austral summer operational period, traverse activities would utilize the facilities and services of one or more supporting stations or outlying facilities to provide equipment storage, cargo management, temporary personnel berthing, equipment maintenance and repair, and waste management services. For the austral winter season, it is anticipated that all traverse equipment would be brought to McMurdo Station for maintenance and storage. McMurdo Station is the USAP's largest facility and central supply hub.

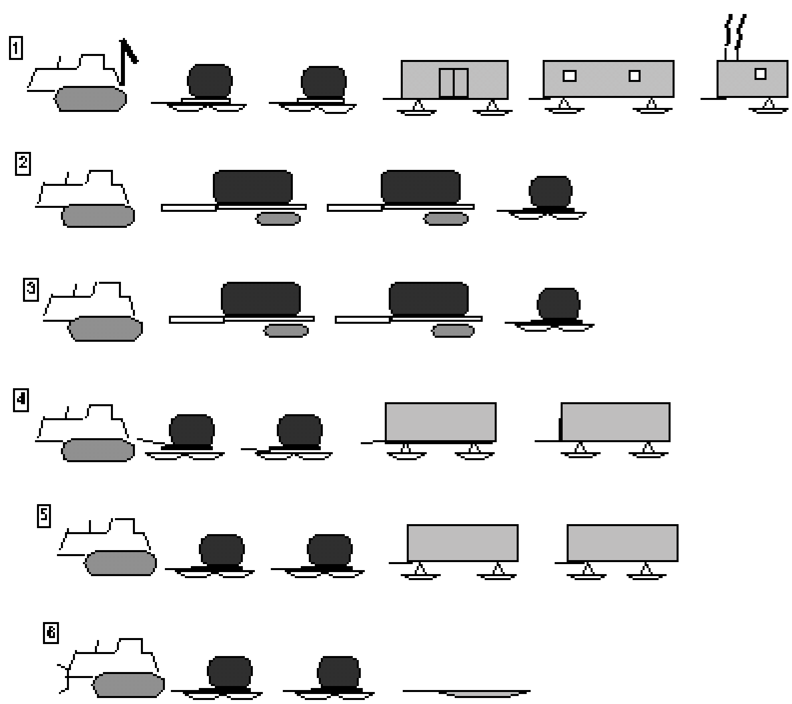
4.3.3 Operating Factors

The performance of re-supply traverse operations may be defined by a series of operating factors including swing configuration, cargo load, and travel time.

Swing Configuration

The configuration of a traverse swing includes the number and type of tractors, trailers, sleds and other specialized equipment used to transport cargo. Each swing would be configured to accommodate the type and quantity of cargo scheduled to be transported as well as the personnel modules, fuel, and supplies needed to support the operation of the traverse. Because of transport efficiencies and safety considerations, it is expected that a minimum of three tractors would be used in any given traverse swing. Figure 4-1 provides a schematic diagram of an example six-tractor swing configuration for a re-supply traverse.

Figure 4-1. Typical Re-supply Traverse Swing Configuration



Cargo Load

Each tractor departing on a re-supply mission would haul an optimally configured payload based on the cargo's weight and volume and the tractor's performance capabilities. Using the surface traverse from McMurdo Station to the South Pole as an example, the maximum payload of each tractor leaving McMurdo would be approximately 43,000 kg excluding the tare weights of the tractor, sleds, and cargo containers. Considering the volume of fuel that would be consumed on a roundtrip traverse mission between McMurdo Station and the South Pole, each tractor could deliver approximately 20,000 to 27,000 kg of cargo.

Travel Time

The travel time required to complete a roundtrip re-supply traverse mission would depend on a number of factors including the distance traveled, equipment power and traction, cargo load, environmental conditions such as crevasses, snow characteristics, slope over the traverse route, and tractor performance. The number of hours each day that the traverse personnel are able to transport cargo would also influence the total duration of a traverse mission.

In the example of the re-supply traverse from McMurdo Station to the South Pole (Appendix A), a 12-hour driving day was assumed resulting in a one-month roundtrip between McMurdo and South Pole.

4.3.4 Field Logistics

Efficient traverse operations require the use of various logistical support mechanisms including the operation of personnel support modules and resources to refuel and maintain the equipment. In addition, the use of fuel caches and supply depots provide the traverse team with resources which do not have to be transported over the entire route but only have to be accessed when they are needed.

Operation of Personnel Support Modules

Personnel support modules for the operating crew would be an integral part of each traverse mission. These modular facilities would provide needed personnel support facilities when the traverse has stopped for the day. Unless delayed by weather or mechanical problems, it is expected these facilities would be operated at a different location along the traverse route each day.

The support modules would contain kitchen, berthing and sanitary facilities, space heating equipment, water production equipment, a portable power plant with approximately 30kW capacity, and waste storage containers. One set of backup facilities will be available. The modules would also be equipped with a workshop and resources for equipment maintenance.

All wastes generated during operations of the traverse equipment would be handled in accordance with 45 CFR §671 and documented for *USAP Master Permit* (reference 3) reporting purposes. All nonhazardous and Antarctic Hazardous wastes generated during the traverse activities would be containerized and returned to a supporting station or outlying facility for further processing and disposition. Sanitary wastes would be either containerized or discharged to snow covered areas as allowed by 45 §CFR 671 and the *USAP Master Permit*.

Equipment Refueling, Maintenance, and Repair

Each swing would contain the resources and equipment to refuel the tractors and to perform limited but essential maintenance in the field. Based on the type of equipment expected to be used and expected fuel consumption rates, it is anticipated that the tractors would be refueled at least daily. To prevent accidental releases (spills) to the environment, the traverse crew would follow specific refueling and maintenance fluid handling procedures and will use fuel distribution equipment and containment devices (drip pans, absorbants) appropriate for the conditions.

Depending upon the length of a particular traverse mission, it is expected that minor equipment maintenance activities will be necessary in the field. Although it is unlikely based on the proven reliability of the proposed equipment, it is possible that some equipment may fail and repair would be beyond the capability of the traverse team. In these instances, the disabled equipment could be repaired using parts and mechanics deployed to the field via aircraft; the equipment could be loaded onto a trailer and towed to a supporting facility; or the failed equipment could be secured in the field for subsequent retrieval by another traverse team.

Field Caches

To optimize operational efficiency, it may be useful to temporarily deposit critical supplies for the traverse in field caches and access these materials when they are needed. For example, to support a re-supply traverse to the South Pole, it may be practical to reduce the payload of each tractor by staging fuel for the traverse equipment along the route. These caches could be established by other traverse operations or airlift support. Similarly, it may be practical to leave some fuel and other supplies at strategic locations along the traverse route so that these items could be accessed when needed on the return leg of the traverse as opposed to transporting them for the entire trip.

All supplies temporarily cached along the traverse route would be positioned and marked so that they can be easily located and recovered without damage to the containers. It is expected that all staged or cached supplies would be recovered at the completion of traverse activities each austral summer, although it may be beneficial to pre-stage some materials in the field for the following austral summer season. All field caches would be deployed and managed as specified in the *Standard Operating Procedure for Placement, Management, and Removal of Materials Cached at Field Locations* (reference 1).

4.3.5 Off-season Activities

Most re-supply traverse activities are expected to be conducted during the austral summer, typically October through February. During the off-season (austral winter), it is anticipated that all equipment would be stored at or in the immediate vicinity of McMurdo Station and mechanical equipment maintained at the Vehicle Maintenance Facility (VMF). Personnel support modules would be inspected, winterized, maintained, and restocked for subsequent use.

At the beginning of each operating season, traverse equipment, including the tractors, trailers, and personnel support modules would be mobilized, prepared for use, and staged accordingly. Williams Field, located ten kilometers from McMurdo Station on the permanent ice sheet, would be a practical staging area for re-supply cargo being transported to the Amundsen-Scott Station.

4.4 Description of Surface Traverses for Scientific Research

A fully developed USAP traverse capability could provide the resources including the equipment, trained personnel, and logistical procedures needed to perform various types of scientific research in Antarctica. In general, it is assumed that a traverse used for scientific research would cover an area or undeveloped route that was selected to achieve specific research goals. Unlike a re-supply traverse mission, a research traverse would only need to transport the cargo needed to perform the intended research and support the personnel and traverse equipment while in the field. Variable characteristics which can be used to describe science-related traverse activities include the route or area to be surveyed, resources to be used, operating factors, and field logistics. These characteristics would be optimized to meet the specific goals of the research.

The entire range of research activities that may be performed on science-related traverses is dependent on the goals of future researchers and cannot be projected and analyzed in this CEE. The scope of this environmental review is intended to focus on the mechanics of conducting a traverse used for scientific research purposes. Potential impacts resulting from the scientific aspects of the research performed on a traverse would be evaluated, if they have not been addressed elsewhere, in additional environmental reviews supplementing this CEE. The recently completed International Trans Antarctic Scientific Expedition (ITASE) is an example of a science-related traverse used to identify potential impacts associated with this type of traverse activity (Appendix B). The following describes typical characteristics of a science-related traverse.

4.4.1 Traverse Route

Traverse activities for science applications would utilize a route designed to meet the particular objectives of the research. The traverse route may consist of transects between defined points, circular routes, or series of branches from a central location. A science-related traverse may be conducted on a new route, a route previously used for research, or a route used for a re-supply mission. Summaries of the past scientific traverses that have been conducted by numerous Treaty nations, including the United States, in virtually every region of Antarctica was presented in Section 2. Under the proposed action, science-related traverse routes that extend into environmental settings which are different than those characterized in this CEE (e.g., Ross Ice Shelf, Polar Plateau) would require supplemental environmental review.

It is assumed that most traverses conducted for scientific research activities would utilize an unimproved and unmarked route, which may only be used once. It is anticipated that each science-related traverse route would be inspected for crevasse hazards using ground penetrating radar, infrared photography, or other remote sensing methods. Given the resources that may be typically available on a science-related traverse, crevasses would be avoided when practical as opposed to mitigation through exposure and fill.

4.4.2 Resources

The resources needed to conduct a science-related traverse include equipment, personnel, support infrastructure system, fuel, and supplies. The magnitude of resources utilized may alter or impact the effectiveness of traverse operations as well as the nature and extent of environmental impacts.

Equipment

The equipment that would be used in a science-related traverse will comprise, in general, two or more tracked vehicles towing a series of trailers or other equipment. The size of the powered equipment may be large (e.g., Caterpillar Challenger) if heavy loads are anticipated or small (e.g., Tucker Snocat, Kassbohrer Pisten Bully, LMC Spryte, snowmobiles) if suitable for the intended purpose. Tracked trailers or sled-mounted trailers may be used as well as containers modified for specialized purposes (e.g., ice core storage).

The ITASE traverse activities conducted during the 2002-03 austral summer season provides an example of the type of equipment that may be used on a science-related traverse. The ITASE traverse used two Caterpillar Challenger 55 tractors towing more than ten trailers consisting of modules for personnel support, science equipment, and mechanical workspace, and containers for food, fuel, and related supplies. Each of the Challenger 55 tractors was capable of hauling approximately 20,000 kg of material.

Personnel

The number of personnel and skills used to perform scientific traverses and surface-based surveys would be based on the scientific goals of the mission and the operational needs of the traverse itself such as equipment operators, mechanics, support camp operations, first aid, mountaineering, communications, and spill response. For example, the recent ITASE traverse utilized a total of 13 staff, including the field team leader, nine scientists and technicians, mechanic, camp manager, and cook.

Personnel Support Modules

Personnel support modules for the research and operating crew would be an integral part of each traverse mission. Each traverse is expected to transport at least two personnel modules containing the life support facilities needed for the staff (e.g., berthing, food service, lounge). Separate primary and backup modules would be available to prevent the loss of both in a single accident. The primary and backup modules would be capable of berthing and feeding the whole traverse team, and will include power generation, potable water production, heating, and communications equipment. Unless delayed by weather or mechanical problems, it is expected these facilities would be operated at a different location along the traverse route each day.

Fuel and Supplies

In addition to science-related materials, each traverse would require fuel, lubricants, maintenance supplies, spare parts, food, other expendables, and waste containers. To optimize operations, scientific traverses may be designed to minimize the amount of fuel and supplies that are transported over the entire traverse route by periodically utilizing airlift support or pre-staged field caches for re-supply.

The cargo and liquid containers used on the traverse would be structurally compatible with their contents and able to withstand the physical and environmental conditions to be encountered during the traverse. It is expected that fuel tanks would be equipped with secondary containment. Other supplies needed for the traverse equipment or maintenance activities such as gasoline, lubricants, and coolants would be transported and stored in 208-liter (55-gal) drums. Each traverse or surface-based survey party would be equipped with the containers needed to collect and manage all wastes generated during the traverse, including solid and hazardous and sanitary wastes.

Support Facilities and Services

Scientific traverses and surface-based survey parties may utilize the facilities and services of a supporting station or outlying facility to facilitate the management of supplies, equipment, or scientific samples. These services may include equipment storage and maintenance, cargo management, interim personnel berthing, and waste management services. As the USAP's largest facility and central supply hub, McMurdo Station is expected to serve as the primary traverse staging and resource facility although other sites may be used as secondary support facilities as well. For example, the recent ITASE traverse used the Byrd Surface Camp as a base of operations for traverse staging and preparation.

4.4.3 Operating Factors

Traverse Configuration and Equipment Load

Each tractor would haul the facilities and materials needed to conduct the intended research as well as personnel support modules, fuel, and supplies needed to support the traverse itself. The load hauled by each tractor would depend on the quantity of equipment and materials to be transported, the terrain to be encountered, and the tractor's performance.

For the recent ITASE traverse from Byrd Surface Camp to the South Pole, each Caterpillar Challenger 55 tractor had the capacity to tow a load of approximately 20,000-kg while consuming fuel at a rate of 29.1 liters per hour.

Schedule

The schedule of scientific traverse activities and surface-based surveys would be designed to meet the specific goals of the project and must be compatible with the schedule for logistical resources needed to support the research efforts. Science-related traverse activities may include periods of travel interspersed between data gathering (e.g., field measurements, sample collection) activities. The travel schedule would be affected by the equipment operating speed and daily operating hours.

In the recent ITASE, a total 1,250 km of terrain was traversed over a 40-day period including stops at several sites occupied for 2-3 days each. Along some sections of the ITASE traverse, snow conditions caused a slower operating speed (5 km per hour) compared to usual travel speeds of 10-12 km per hour.

4.4.4 Field Logistics

Efficient science-related traverse operations require the use of various logistical support mechanisms including the operation of personnel support modules and resources to refuel and maintain the equipment. In addition, the use of fuel caches and supply depots provide the science traverse team with resources which do not have to be transported over the entire route but only have to be accessed when they are needed.

Operation of Personnel Support Modules

Personnel support modules for the science and traverse operating crew would be an integral part of each traverse mission. These modular facilities would provide living facilities for the personnel when the traverse has stopped for the day. When moving, it is expected these facilities would be operated at a different location along the traverse route each day; when stopped for weather or mechanical problems, or for data collection, a several-day occupation can be expected.

The support modules would contain kitchen, berthing and sanitary facilities, space heating equipment, water production equipment and power generation equipment necessary to support the proposed staff. Backup facilities would be available. The modules would also be equipped with a workshop and resources to perform equipment maintenance and minor equipment repair as needed.

All wastes generated during operations of the traverse equipment would be handled in accordance with 45 CFR §671 and documented for the *USAP Master Permit* (reference 3) reporting purposes. All nonhazardous and Antarctic Hazardous wastes generated during the traverse activities would be containerized and returned to a supporting station or outlying facility for further processing and disposition. Sanitary wastes would be either containerized or discharged to snow covered areas as allowed by 45 §CFR 671 and the *USAP Master Permit*.

Equipment Refueling, Maintenance, and Repair

Each science-related traverse or surface-based survey would contain the resources and equipment to refuel the tractors and to perform limited but essential maintenance in the field such as the addition of lubricants and coolants. Based on the type of equipment expected to be used and associated fuel consumption rates, it is anticipated that the tractors would be refueled daily. To prevent accidental releases such as spills to the environment, the traverse crew would follow specific refueling procedures and will use fuel distribution equipment and containment devices (e.g., drip pans, absorbents) appropriate for the conditions.

Depending upon the length of a particular traverse mission, it is expected that minor equipment maintenance activities may be necessary in the field. Although it is unlikely based on the proven reliability of the proposed equipment, it is possible that some equipment may fail and repair would be beyond the capability of the traverse team. In these instances, the disabled equipment could be repaired using parts and mechanics deployed to the field via aircraft; the equipment could be loaded onto a trailer and towed to a supporting facility; or the failed equipment could be secured in the field for subsequent retrieval by a recovery team.

Field Caches

To optimize operational efficiency, it may be useful to temporarily deposit critical supplies for the traverse in field caches and access these materials when they are needed. For example, to support a science-related traverse or surface-based survey, it may be practical to reduce the payload of each tractor by staging fuel for the traverse equipment along the route. These caches could be established by other traverse operations or airlift support. Similarly, it may be practical to leave some fuel and other supplies at strategic locations along the traverse route so that these items could be accessed when needed on the return leg of the traverse as opposed to transporting them for the entire trip.

All supplies that would be temporarily cached along the traverse route will be positioned and marked so that they can be easily located and recovered without damage to the containers. It is expected that all staged or cached supplies would be recovered at the completion of traverse activities each austral summer, although it may be beneficial to pre-stage some materials in the field for the following austral summer season. All field caches would be deployed and managed as specified in the *Standard Operating Procedure for Placement, Management, and Removal of Materials Cached at Field Locations* (reference 1).

4.4.5 Off-season Activities

Most science-related traverse activities are expected to be conducted during the austral summer, typically October through February. During the off-season (austral winter), it is anticipated that all equipment would be stored at or in the vicinity of McMurdo Station and mechanical equipment maintained at the VMF. During the austral winter and in preparation for science-related traverse activities planned for the future, equipment would be selected and customized as needed. In addition, supplies for future field caches would be assembled and prepared for transport to the field.

4.5 Nature and Intensity of Proposed Activities

Surface traverse activities intended to be used for re-supply or scientific research missions would generally include motorized tracked vehicles towing sleds or trailers which contain fuel for the tractors, living and working modules for the traverse personnel, cargo, and other materials as needed. The following describes the nature and extent of the traverse activities used for re-supply and science-related purposes.

4.5.1 Re-supply Traverse

The USAP intends to develop and implement a surface re-supply traverse capability to supplement existing airlift resources and optimize the transportation of fuel, cargo, and supplies to selected USAP facilities. In general, re-supply traverses would consist of a convoy of tractors operating on a routine basis along a marked, improved route.

In order to identify and evaluate potential environmental and organizational impacts associated with the performance of re-supply traverses, the re-supply of the Amundsen-Scott Station has been selected as an example for analysis. Appendix A provides an engineering analysis of the use of the traverse capability to re-supply the Amundsen-Scott Station from McMurdo Station thereby supplementing existing airlift resources. In this analysis, each roundtrip of a traverse team is called a swing. Table 4-1 summarizes various practical alternatives for the re-supply of the Amundsen-Scott Station by surface traverse operations.

Table 4-1. Projected Re-supply Traverse Operations

Alternative	No. of Roundtrips per Season	No. of Tractors Towing Cargo Sleds	Typical Quantity of Cargo Transported per Traverse (kg)	Cargo Delivered per Season (kg)
A (optimal configuration)	6	6	133,000	800,000
B (minimal frequency)	3	6	133,000	400,000
C (reduced intensity)	6	3	67,000	400,000
D (minimal field support)	6	6	128,000	768,000
E (existing routes only)	6	6	133,000	800,000
F (no action)	0	0	0	0

Alternative A – Develop Traverse Capability and Implement Routine Use and Optimal Configuration

The surface re-supply traverse that would be conducted in Alternative A would be optimally configured to be used in conjunction with existing airlift support resources. The South Pole re-supply traverse would utilize the route developed by the proof of concept effort and would consist of six swings per year comprising six tractors per swing. It is expected that the traverse in this alternative will be capable of delivering up to 800,000 kg of cargo and fuel per year to the South Pole.

Based on the traverse distance and route, anticipated equipment operating speed, and 12-hour operating shift per day, each roundtrip from roundtrip from McMurdo Station to the South Pole would require approximately 30 days to complete. The frequency of each traverse would be designed to efficiently accommodate the austral summer operating period of the Amundsen-Scott Station. It is anticipated that the re-supply traverse swings to the South Pole could depart McMurdo Station from 20 October through 15 January while still allowing sufficient time for the complete roundtrip.

Each swing would be configured to accommodate the specific type and quantity of materials scheduled for delivery to the South Pole. It expected that each optimally configured swing would be capable of delivering approximately 133,000 kg of cargo or fuel to the South Pole as well as transporting equipment, fuel, and supplies needed to sustain the operation of traverse. Cargo loads may be increased slightly by using field caches or depots of fuel and supplies strategically placed along the traverse route.

In the optimal configuration for the South Pole re-supply traverse, each swing would be staffed by six people, one operator per tractor. The team would be trained to provide specialized operations and emergency skills. Remote control technology could potentially be used to operate one or more tractors slaved together thereby allowing fewer personnel to operate the traverse.

Alternative B – Develop Surface Traverse Capability and Implement at a Minimal Frequency

Alternative B re-supply traverse activities would occur on the same route and operating conditions as described in Alternative A but would transport less cargo since there would be only three traverse swings per year using six tractors per swing. This alternative would not provide the optimum use of personnel and equipment needed to develop a traverse capability in the USAP.

Alternative C – Develop Surface Traverse Capability and Implement at a Reduced Intensity

Alternative C re-supply traverse activities would occur on the same route and operating conditions as described in Alternative A but would transport less cargo since there would be only three tractors per swing and six swings per season. This alternative may be practical if only a limited amount of traverse equipment was available but it would not be optimal since the re-supply needs of the Amundsen-Scott Station far exceed the amount of cargo that could be delivered.

Alternative D – Develop Surface Traverse Capability and Implement With Minimal Use of Field Support Resources

Re-supply traverse activities that will be conducted in Alternative D would be optimally configured but would be restricted from using field support resources such as field caches, depots, or support camps. The potential benefit in reducing the use of field resources is that hazardous materials ultimately spend less unattended time outside of USAP stations. Each swing that would be conducted in this alternative would need to be configured to transport at all times all of the fuel and materials needed to sustain itself for the entire roundtrip and; therefore, may not realize maximum efficiencies.

Alternative E – Develop Surface Traverse Capability and Implement Using Only Existing Routes

In this alternative, re-supply traverses would be performed using the optimal configuration, but would be limited to using only existing traverse routes in Antarctica. A potential route between McMurdo Station and the Amundsen-Scott Station is being evaluated as part of the ongoing proof of concept study. If this traverse route is determined to be successful, it, as well as existing traverse routes used by other nations, could be utilized for re-supply missions.

Alternative F – The USAP Does Not Develop a Traverse Capability (No Action Alternative)

For the no action alternative, the USAP would not develop a surface traverse capability and would continue to exclusively use airlift resources for re-supply missions. All materials that would be delivered to the Amundsen-Scott Station and other USAP facilities would be subject to the same airlift transport limitations (e.g., size, weight, schedule, weather, flight availability) that must be currently considered for logistics planning. In this alternative, airlift resources currently programmed for re-supply missions could not be reprogrammed to support new surface-based scientific research activities.

4.5.2 Scientific Traverses and Surface-Based Surveys

The USAP as well as other nations currently use science-related traverses or surface-based surveys to support in-field research activities. Since the USAP does not have a fully-developed traverse capability, research proposals requesting traverse support must be addressed on an ad hoc basis using existing resources. The proposed action would provide the USAP with enhanced traverse capabilities to support new research opportunities. In addition, the development and implementation of a USAP capability to support new science-related needs may reduce the reliance on airlift resources.

Because the technical scope of some future research proposals would be specifically designed to employ the use of science-related traverse activities or surface-based surveys, there are no relevant alternatives other than performing the research as proposed or not doing it at all. As such, this environmental review will focus on the identification and evaluation of the potential environmental and organizational impacts associated with the mechanical aspects (e.g., terrain disturbance, exhaust gas emissions, releases of substances to the environment) of performing traverses and surface-based surveys for science-related purposes. Potential impacts associated with the performance of the science-related activities such as ice coring, sample collection, or installation of monitoring equipment would be evaluated in separate environmental reviews, as needed.

As an example, the 2002-03 ITASE traverse (Appendix B) conducted glaciological and atmospheric research along a 1,250 km route and eight designated monitoring locations between Byrd Surface Camp and the South Pole. The traverse comprised two tractors towing more than ten trailers containing science equipment, workspaces, personnel support modules, fuel, and supplies. The 2002-03 ITASE traverse proceeded for approximately 40 days and was staffed by 13 scientists and support personnel.

It is expected that most scientific traverses would be designed to operate with a minimal cargo load by incorporating the strategic use of pre-staged field support resources. The 2002-03 ITASE traverse utilized airlift support to provide field caches of fuel and other supplies at key locations along the traverse route. In this way, the science-related traverse did not have to transport all of the fuel and other supplies needed for the entire expedition. If appropriate to support future research activities, field caches containing fuel, equipment, or supplies may remain in the field for multiple operating seasons.

As needed for the research, workspaces and personnel support modules may be operating while moving and when stopped at temporary camps or monitoring locations. Facilities needed to support these operations include power generators, heaters, a snowmelter, and communication equipment. All wastes would be collected and managed consistent with 45 CFR §671 and procedures for field camp operations describe in the *USAP Master Permit* (reference 3).

Equipment maintenance would be performed as needed during science-related traverse activities available resources. In general, only minor routine or preventative maintenance would be performed. Should the failure of a piece of mechanical equipment be beyond the repair capabilities of the traverse team, either a repair crew will be flown to the site; the equipment would be towed to a supporting facility; or the equipment would be secured in the field and identified for subsequent recovery.

5.0 AFFECTED ENVIRONMENT

5.1 Introduction

The affected environment includes the physical conditions on the Ross Ice Shelf (Section 5.2), Transantarctic Mountains (Section 5.3), and Polar Plateau (Section 5.4). Since traverse activities may have broader impacts, the affected environment also includes the operations at McMurdo Station (Section 5.5) and other USAP Facilities (Section 5.6), scientific research conducted in the USAP (Section 5.7), and social conditions in the Antarctic (Section 5.8) including the historical resources, cultural resources and heritage, and wilderness values. This description of the affected environment represents the initial environmental state (i.e., existing conditions).

The exact locations of surface traverse activities that may be conducted as a result of the proposed action cannot be predicted in this CEE. The scope of this environmental review focuses on potential routes which may traverse ice and snow-covered inland areas (e.g., Ross Ice Shelf, Transantarctic Mountains, Polar Plateau). The scope of this review specifically excludes traverse routes crossing or in proximity to dry land, areas covered by temporary sea ice, areas which support wildlife, and Antarctic Specially Protected Areas (ASPAs). Traverse routes that are planned in areas not specifically addressed by this CEE will require supplemental environmental review.

5.2 Ross Ice Shelf

The Ross Ice Shelf is a large snow-covered body of floating glacial ice located between 155^0 and 160^0 E longitude and 78^0 and 86^0 S latitude in Antarctica and bordered by the Transantarctic Mountains, the McMurdo Ice Shelf, Marie Byrd Land, and the Ross Sea (see Figure 2-4). The ice shelf is approximately 965 km long and covers an area of 540,000 square km. The shelf was formed by inputs from ice streams and glacier flows and is grounded along coastlines and on shallow parts of the Ross Sea. Thickness of the ice shelf ranges from 100 to 900 meters.

The McMurdo Ice Shelf is adjacent to the Ross Ice Shelf near McMurdo Station on Ross Island. The "shear zone" is a four-kilometer long area approximately 35 km from McMurdo Station between the slow, generally westward-moving McMurdo Ice Shelf and the faster, northward-moving Ross Ice Shelf. The shear zone is a heavily-crevassed area that must be crossed to reach areas west of McMurdo Station. As part of the South Pole traverse proof of concept study, a total of 32 crevasses were mitigated in the shear zone during the 2002-03 austral summer to allow safe passage by equipment.

The annual mean temperature recorded at McMurdo Station is -18^0C with temperature extremes of -50^0C and 8^0C. The prevailing wind direction is from the east with an average velocity of 5.1 meters per second (m/sec). The annual average snow accumulation on Ross Island is 17.6 cm (water equivalent). Drifting snow can result in accumulations of 1.5 m or more per year.

5.3 Transantarctic Mountains

The Transantarctic Mountains provide a natural division of Antarctica. They are approximately 3,000 km long, dividing the continental into West Antarctica (30°E to 165°W longitude, moving in an anti-clockwise direction) and East Antarctica (30°E to 165°W longitude, moving in a clockwise direction). The glacier-mantled peaks of the Transantarctic Mountains rise high above the western shore of McMurdo Sound and the Ross Sea, 90 km from Ross Island. Several large valley glaciers flow from the Polar Plateau through gaps in the range, some joining the Ross Ice Shelf and some flowing directly into McMurdo Sound. Nearly 20 glaciers connect the Polar Plateau to the Ross Ice Shelf; many of the largest, including the Beardmore and the Skelton, have been used as surface traverse routes in the past.

Prevailing winds in the Transantarctic Mountains are downslope katabatic (gravity driven), in contrast to the easterly winds of the Ross Ice Shelf. Snow cover in the mountainous areas is variable and is influenced by localized wind and weather patterns.

5.4 Polar Plateau

The interior of Antarctica is composed of two major, geologically distinct parts (i.e., East and West Antarctica) buried under a vast ice sheet (i.e. the Polar Plateau). East Antarctica, the larger of the two, is roughly the size of the United States and is composed of continental crust covered by an ice sheet that averages 2,160 m in thickness. The ice sheet is also composed of two distinct parts. The larger portion, the East Antarctica Ice Sheet, rests on land that is mostly above sea level, while the smaller West Antarctica Ice Sheet is grounded below sea level, in places over 2.5 m below sea level. These two ice sheets cover all but 2.4 percent of Antarctica's 14 million square kilometers. Nearly 90 percent of the ice flowing across West Antarctica converges into ice streams that are the most dynamic, and perhaps unstable, components of the ice sheet. At the South Pole, the ice sheet is approximately 3 km in depth and is constantly shifting, at the rate of about nine meters per year.

Temperatures in the interior of the continent are extremely cold. Earth's lowest surface temperature (-88°C) was recorded at Russia's Vostok Station, and the mean annual temperature at the South Pole is -49.3°C. Temperatures recorded at the South Pole have ranged from a minimum of -80.6°C to a maximum of -13.6°C. Mean monthly temperatures range from -60°C in July and August to about -28°C in December and January.

Annual snowfall in much of the interior is less than five centimeters. As the snow accumulates on the surface of the Polar Plateau in the extremely dry and cold atmosphere, it forms what is referred as a "firn", a very dry form of snow with a mean density near the surface of approximately 0.3 to 0.4 g per cubic centimeter (g/cm^3). The snow compacts with depth until, at approximately 100 m below the surface, it attains a density of about 0.8 g/cm^3 where it has become glacial ice. As the depth of the polar ice sheet increases, density increases and many voids are compressed, forming a very clear and uniform mass of ice relatively free of fissures and cracks.

On the Polar Plateau, the high elevation and the gradually sloping ice sheet provide for a physical environment that yields persistent and predictable winds. The South Pole is located within a persistent polar anticyclone anchored by the elevated continental ice sheet. The average wind speed at the South Pole is typically less than six meters per second, with peak winds rarely over 10 m/sec, and a predominant wind direction of approximately 40 degrees E longitude. Winds that flow down the surface of the ice sheet toward the coast (katabatic winds) commonly reach speeds of 35 m/sec, and maximum measured wind speeds have exceeded 80 m/sec.

5.5 McMurdo Station

McMurdo Station is the largest facility in Antarctica, and is located on the Hut Point Peninsula on Ross Island. The station includes over 100 buildings, comprising research facilities and associated infrastructure. The station operates year-round and can support a peak population of approximately 1,200 people during the austral summer. McMurdo Station serves as the primary logistical support hub for the USAP, and the station resources would be used, as needed, to develop re-supply and scientific traverse capabilities.

The primary resources that McMurdo Station would provide to support a surface traverse capability include equipment and vehicle maintenance services using the Vehicle Maintenance Facility (VMF) and Science Support Center (SSC). The VMF is responsible for maintaining and repairing a fleet of over 140 large- and medium-sized vehicles based in the McMurdo area which cumulatively operate 130,000 hours per year. The SSC maintains and repairs the fleet of smaller vehicles (e.g., snowmobiles, LMC Sprytes, Kassbohrer Pisten Bullies) and powered equipment (e.g., generators, ice drills). Other McMurdo Station resources that would be used to support traverse operations include:

- Temporary personnel support (e.g., berthing, food service)
- Supplies (e.g., food)
- Fuels (e.g., diesel, gasoline)
- Waste management (e.g., containers, handling)
- Weather support
- Communications support
- Airlift support (e.g., airdrops, cargo transport)
- Equipment storage (austral winter)

5.6 Other USAP Facilities

In addition to McMurdo Station, the USAP operates other facilities in Antarctica, including one permanent station at the South Pole (Amundsen-Scott Station), one permanent coastal station on the Antarctic Peninsula (Palmer Station), and permanent support facilities, outlying facilities (e.g., major and minor field camps), unmanned instrumentation sites, and field caches located throughout the continent. Depending on the needs of the USAP, re-supply or scientific traverse missions may be conducted to, or supported by, any of these facilities.

The Amundsen-Scott Station is located on the Polar Plateau at the Geographic South Pole (90^0S) and could be serviced by re-supply traverses or involved in the performance of science-related traverse activities. The station supports a variety of scientific activities, and is occupied year round. Depending on the extent of research and station operations, the austral summer season population may be 150 while the winter population would normally be less than 50 people. The station includes over 60 buildings and various types of towers, antennas, and related structures placed on the snow surface. A 3,000-meter skiway is maintained for ski-equipped aircraft. Logistical support to the station is provided exclusively by ski-equipped LC-130 Hercules aircraft. Most of the LC-130 airlift support resources operated by the USAP each year are used to service the South Pole. Construction of a new primary facility at South Pole has required considerable aircraft support for the delivery of building materials. The new facility is nearing completion, when it is expected that delivery needs will drop to a lower level.

Williams Field, a skiway located 16 km from McMurdo on the snow-covered Ross Ice Shelf, may also be used to support traverse operations during the austral summer. Williams Field comprises a series of ski-mounted structures, facilities, and equipment used for runway maintenance, aircraft support, and logistical support, such as fuel distribution and cargo handling. In addition, Williams Field has several semi-permanent structures and the Long Duration Balloon (LDB) Camp, which is operated each austral summer to support atmospheric science projects. Because the facilities at Williams Field are located on the Ross Ice Shelf and separate from McMurdo Station, it would be a practical location to base a majority of the traverse staging activities such as cargo loading, unloading, and equipment storage.

Each austral summer season, the USAP operates numerous outlying facilities to support scientific research performed at field sites throughout the Antarctic continent. These outlying facilities include:

- Major Field Camps in snow/ice covered areas (typically five per season and occupied more than 400 person-days per year)
- Minor Field Camps in snow/ice covered areas (typically 26 per season and occupied less than 400 person-days per year)

- Minor Field Camps in dry land areas (typically 16 per season and occupied less than 400 person-days per year)
- Minor Field Camps on the seasonal sea ice or coastal areas (typically six per season and occupied more than 200 person-days per year)
- Field Caches (typically 61 per season and unmanned)
- Unmanned Instrumentation Sites (typically 123 per season and unmanned)

Most of the field camps operated by the USAP each year are minor camps possessing few structures (e.g., tents) and are used on a temporary basis (i.e., one or two seasons). Unmanned field caches and instrumentation sites are typically maintained for multiple years. The locations of these outlying facilities will depend on the specific goals of the research to be performed or supported.

5.7 Scientific Research in the USAP

Each year, surface-based scientific research is performed at two of the three U.S. year-round stations (McMurdo, Amundsen–Scott), outlying facilities, and remote field locations, while marine-based research is conducted primarily at Palmer Station and from research vessels operating in the Southern Ocean. Projects supported in Antarctica by the USAP include research in aeronomy and astrophysics, biology and medicine, ocean and climate studies, geology and geophysics, glaciology, and long-term ecological research (LTER). During the 2002-03 austral summer, nearly 700 researchers and special participants conducted 141 projects, including surface traverse-based studies of the International Trans-Antarctic Scientific Expedition (ITASE) in West Antarctica (reference 4).

Scientific traverses may be used to provide a platform for specialized scientific research or advanced surface-based studies in one or more of the research fields. The nature of future surface-based science projects is dependent on the goals of each researcher and cannot be predicted; however, using results derived from recent satellite-based work (e.g., Radarsat, Landsat) and airborne geophysics, the science community has identified the need for the collection of specific data that can allow for the interpretation of the variability of glaciological, geological, climatological, atmospheric, and other parameters on short distance scales (reference 2).

5.8 Social Conditions

Social conditions in Antarctic represent the human environment and include a rich cultural history, as well as the aesthetic resources such as the wilderness value of the vast continent. The historical and cultural resources of Antarctica date back to the early explorations of the continent performed on behalf of many nations. Section 2 provided a description of prominent surface traverse efforts which have contributed both to the cultural history of Antarctic exploration as well as the scientific knowledge gained through the collection of data in the Antarctic environment. While reaching the Geographic South Pole was a primary goal of early 20th century explorers, efforts to map areas of the continent and collect scientific data were also important objectives. As technology and efficient transportation mechanisms progressed, many parts of Antarctica were visited and subsequently became available for study. The human experience in each area of the continent has contributed to the cultural history of the Antarctic, and maps, photographs, journals, and other publications have all played an important role in documenting this history. In recent years, this documentation has expanded through the use of the Internet, and has even incorporated the experience of individual participants involved in specialized activities such as surface traverses. It is expected that these efforts will continue in the future.

Some human activities commemorate Antarctica's exploration. At the Seventh Antarctic Treaty Consultative Meeting it was agreed to create a list of historic sites and monuments. To date, a total of 74 sites have been identified as documented in the *Antarctic Conservation Act of 1978* (Public Law 95-541) and referenced in Article 8 of *Annex V to the Protocol on Environmental Protection to the Antarctic Treaty*. All of the current historic sites and monuments are related to human experiences, and some are located in proximity to scientific stations. In addition, the historical resources of the Ross Island area have been described in the *Historic Guide to Ross Island, Antarctica* (reference 5).

Aesthetic resources of Antarctica are not readily defined, but can generally be characterized as the wilderness value, or an area without permanent improvements or visible evidence of human activity. The remote areas of Antarctica that exist in locations away from established stations, field camps, and infrequently visited terrain allow visitors to experience the remoteness of the continent and the unique Antarctic environment.

6.0 DESCRIPTION OF ENVIRONMENTAL IMPACTS

6.1 Introduction

This portion of the Comprehensive Environmental Evaluation (CEE) identifies potential impacts that may occur as a result of, or in association with, the proposed action to develop and implement surface traverse capabilities in Antarctica. Section 6.2 discusses the methods and sources of data used to identify, quantify, and evaluate the potential impacts. Section 6.3 describes the nature and extent of activities that have the potential to yield impacts to the Antarctic environment resulting from the proposed performance of surface re-supply traverses. Similarly, Section 6.4 identifies potential environmental impacts associated with the performance of science-related traverse activities.

Potential impacts to the environment that are described in Sections 6.3 and 6.4 include operational impacts that may be realized at McMurdo Station, other USAP facilities, including the Amundsen-Scott Station, and potential impacts to scientific research in the USAP and to the social conditions in the Antarctic, including historical, cultural heritage, and wilderness values. Additional impacts that may result from the use of surface traverses include indirect or second-order impacts, cumulative impacts, and unavoidable impacts; they are described accordingly. Section 6.5 presents a summary of all foreseeable potential impacts caused by the development and use of surface traverse capabilities in the USAP.

6.2 Methodology and Data Sources

The proposed action in this CEE involves the development and implementation of surface traverse capabilities by the USAP. A specific purpose or route for future traverse activities cannot be definitively stated at this time. In order to identify and assess potential environmental and operational impacts associated with the use of surface traverse capabilities, two representative traverse examples were selected for analysis. The first involves the re-supply of the Amundsen-Scott Station at the South Pole by surface traverse from McMurdo Station. The second involves the performance of a science-related traverse such as the 2002-03 International Trans Antarctic Scientific Expedition (ITASE). Data available from these two examples serves to characterize typical traverse operations, including equipment and personnel resources, operating factors, field logistics, and other support needs that may have environmental and operational impacts. The methods used to evaluate potential environmental and operational impacts associated with re-supply traverse activities are similar to those described in the Environmental Document and Finding of No Significant and Not More Than Minor or Transitory Environmental Impact entitled *Develop Proof of Concept Traverse from McMurdo Station, Antarctic to the South Pole* (reference 6).

The initial environmental state presented in chapter 5 described the conditions currently existing at the Ross Ice Shelf, Transantarctic Mountains, and Polar Plateau, and selected USAP facilities, in the absence of the proposed action. Potential environmental impacts resulting from operation of USAP facilities and logistical support systems, including aircraft, have already been evaluated in the *U.S. Antarctic Program Final Supplemental Environmental Impact Statement* (reference 7). The USAP provides further continuous monitoring and assessment of potential environmental impacts using data compiled for the *USAP Master Permit* (reference 3). These assessments noted that there are more than minor or transitory impacts associated with land use, air quality, waste management, wastewater discharge, fuel spills, or ecological resources, that these impacts are localized and do not result in a major adverse impact to the environment, and that there are no significant long-term and widespread impacts to human health or the environment resulting from operation of USAP facilities.

Potential impacts of the proposed action were identified and evaluated for the following environmental and operational aspects using data characterizing the examples of re-supply and science-related traverses:

- Physical Disturbance to the Snow/Ice Environment
- Air Quality
- Releases to the Snow/Ice Environment
- Impacts to McMurdo Station Operations
- Impacts to Other USAP Facilities
- Impacts to Scientific Research in the USAP
- Impacts to Social Conditions
- Second Order and Cumulative Impacts

6.2.1 Physical Disturbance to Snow/Ice Environment

The extent of physical disturbances that will result from traverse activities was estimated based on traverse route development activities documented for the Proof of Concept study (reference 6) and traverse operations documented in the US ITASE 2002-2003 Field Report (Appendix B). Additional data characterizing disturbances caused by surface traverse activities performed by other Antarctic Treaty Nations were derived from Comprehensive Environmental Evaluations (CEEs) and preliminary environmental assessment documents (references 18-21).

6.2.2 Air Emissions

Air emissions resulting from the operation of equipment (tractors, electrical power generation, heating, ancillary equipment) were calculated using factors compiled by U.S. EPA (references 8 and 9). These calculations, including emissions factors, are presented in Appendices C and D. Data characterizing the fuel consumption rates for traverse equipment operating under Antarctic conditions were derived from the traverse examples (Appendices A and B). Emission rates from the use of explosives were based on factors compiled by U.S. EPA (reference 8). Logistical support aircraft air emissions were derived from U.S. EPA emissions factors (reference 8), the number of hours flown, and the number of takeoff/landing cycles.

6.2.3 Releases to the Snow/Ice Environment

Releases to the snow/ice environment such as the discharge of wastewater were quantified using various models. The volume of wastewater that would be released by a traverse activity was assumed to be equivalent to the volume of water produced and consumed and was estimated using the average per capita water consumption rate for remote field operations (reference 3) and the projected population. Wastewater pollutant loadings (e.g., BOD, total suspended solids) were calculated based on per capita loading factors (reference 3) and the projected population. Minor releases of irretrievable operational materials expected during route development and maintenance activities (e.g., flags, poles) occur on a random basis and could not be quantified.

Accidental releases may include spills or leaks from containers primarily involving liquids, the unrecoverable loss of equipment, or the dispersal and loss of materials and wastes due to high winds. Since accidental releases are not planned, their frequency, magnitude, and composition cannot be projected in advance. Records of previous USAP spills will be compiled and reviewed to identify the types of equipment and operations that pose the greatest risk for accidental releases. Using this failure analysis information, the USAP will design and specify equipment and procedures for use on surface traverses which minimize the potential for accidental spills. In the event of an accidental release, specific procedures and resources will be available to facilitate cleanup and removal of contaminated media (e.g., snow, ice) to the maximum extent practical (see Chapter 7, Mitigating Measures).

6.2.4 Impacts to McMurdo Station Operations

The projected impacts to McMurdo Station operations were evaluated based on a qualitative review of the proposed traverse activities and potential inter-relationships or conflicts with ongoing station operations such as vehicle maintenance, cargo handling and storage.

6.2.5 Impacts to Other USAP Facility Operations

Projected impacts to other USAP facility operations, including Williams Field and the Amundsen-Scott Station, were evaluated based on a qualitative review of the proposed traverse activities and potential inter-relationships or conflicts with station and facility operations.

6.2.6 Impacts to Scientific Research in the USAP

The impact to other science projects in the USAP was evaluated on a qualitative basis by identifying the potential benefits of traverse capabilities to conducting science in the field and by reviewing the needs of current science projects and identifying potential conflicts with the proposed traverse operations.

6.2.7 Impacts to Social Conditions

The impacts to the social conditions in Antarctica were evaluated by examining the historical development and use of surface traverses in Antarctica, the cultural heritage of Antarctic exploration using surface traverse mechanisms, and the wilderness values of the Antarctic environment that may be affected by such actions. Although comprehensive lists of documented re-supply and science –related traverses have been compiled, see Tables 2-1 and 2-2 respectively, the assessment of potential impacts to social conditions in Antarctica is primarily qualitative.

If the USAP proceeds with the development and implementation of surface traverse capabilities, it is possible that other international entities or nongovernmental organizations (NGOs) may choose to use the traverse routes established by the USAP. There are no sources of information available to definitively suggest the extent to which non-USAP entities may use surface traverse mechanisms or USAP routes. Nonetheless, the recent rise in Antarctic tourism suggests that if tour operators have access to the diverse variety of resources needed to transit the surface in Antarctica, they may use USAP traverse routes as well as those developed by other signatory nations.

6.2.8 Second Order and Cumulative Impacts

Quantitative and qualitative indicators were used to evaluate potential second-order impacts. Quantitative characteristics included the estimated number of logistical support flights that would be deferred as a result of traverse activities. Qualitative indicators were used to identify potential conflicts associated with the addition of more equipment, fuel, and other supplies needed to support the development of traverse capabilities into existing USAP systems. Cumulative impact analysis was performed on a qualitative basis, and took into consideration activities expected to occur at the South Pole and other field sites.

6.3 Environmental Impacts Associated with a Re-supply Traverse

The evaluation of potential environmental impacts associated with surface traverses used for re-supply missions are based on the example of modeled traverse activities between McMurdo Station and the South Pole. The analysis of environmental impacts focuses on physical disturbance, air quality, releases to the environment, and impacts to McMurdo Station operations, other USAP facilities, scientific research, and social conditions (i.e. the human environment). Additional impacts that are addressed include indirect or second-order impacts, cumulative impacts, and unavoidable impacts.

The existing environmental conditions in the areas that could potentially be impacted by the proposed action include the Ross Ice Shelf, Transantarctic Mountains, and Polar Plateau. Impacts to flora and fauna in these areas are not expected since the extremely dry, cold, snow-covered terrain in any of these areas does not support local biota. In addition, these inland areas of the continent are not located near any Antarctic Specially Protected Areas (ASPAs) including marine areas, lakes, or ice-free areas where localized impacts could affect nearby receptors. However, if the traverse capabilities developed as a result of the proposed action are used for re-supply missions in other environmental settings, supplemental environmental reviews would be required to identify potential impacts.

The assessment of the potential environmental and operational impacts described below assumes that selected mitigating measures detailed in Chapter 7 would be implemented as part of re-supply traverse activities. If feasible, additional mitigating measures may be developed that would further reduce potential environmental impacts. Certainly, mitigation techniques and protocols will be validated and perhaps modified as a result of monitoring results.

6.3.1 Physical Disturbance to Snow/Ice Environment

Traverse activities will only occur on snow and ice covered areas. Physical disturbance (i.e., terrain alteration) of the snow and ice environment will be a certain outcome resulting from the use of traverse capabilities along any route. An existing traverse route that may be of practical benefit to the USAP includes the 1,600-km route between McMurdo Station and the South Pole that will be a consequence of the recent Proof of Concept evaluation. All traverse activities involving the development and use of routes in areas different than the environmental conditions characterized in this CEE (i.e., Ross Ice Shelf, Transantarctic Mountains, Polar Plateau) would require subsequent supplemental environmental review.

The specific routes that may be used for re-supply purposes are dependent upon the specific needs of the mission and cannot be defined at this time. Nonetheless, it is assumed that any route will require minimal terrain alteration by grooming the surface to create a drivable path which would be approximately five meters wide. In addition, crevasses would either be avoided where practical, or exposed and filled to mitigate potential human and equipment hazards. The terrain would therefore be altered either through the filling of crevasses or the creation of level surfaces or ramps over low areas. Additional physical disturbances along improved routes may occur during required periodic maintenance (e.g., surface grooming) to ensure continued safe and efficient traverse operations.

If needed, crevasses would be mitigated using snow moved from the surrounding area to fill the opening and provide a stable path across the crevasse at an elevation matching the surrounding surface contour. The area of the crevasse to be filled will be tapered upward to yield a path at the surface sufficiently wide enough to accommodate the traverse equipment. Since many of the crevasses would be covered on the surface by snow bridges, it is anticipated that explosives would be used to collapse the bridges and thoroughly expose the underlying crevasses for subsequent mitigation. In general, it is anticipated that snow bridges would be removed for up to 20 m along the length of each crevasse to ensure that the limit of the crevasse is visible and can be safely mitigated. The area and volume of snow that would be moved from the surrounding area to fill the crevasse and create the path would depend on the depth and width of each crevasse.

While the number and size of crevasses to be mitigated will depend on the specific route, based on the USAP's experience with a route between McMurdo and Amundsen-Scott Stations, the largest crevasses encountered were approximately six meters wide and 55 m deep. This size of crevasse would require approximately 9,500 cubic meters of snow to fill, and would typically utilize fill taken from an adjacent 5,250 m^2 area to a depth of 1.8 meters.

Because an established re-supply traverse route may be used multiple times during a year, it is expected that the snow's surface would be regularly disturbed. However, snow will continue to accumulate in these areas either as new snow or blowing and drifting snow, thereby minimizing the duration of the time the route visually appears to be disturbed. As a result, physical disturbance would represent a transitory impact.

During the development of a traverse route intended to be used for re-supply purposes, markers consisting of bamboo poles with cloth flags would be installed to identify the borders of the route, crevasses, obstacles, or other significant features. The markers are expected to remain in the field and would eventually either disintegrate or become covered with snow and ice. The markers would result in a minor, temporary alteration of the terrain.

Incorporating the use of the mitigating measures identified in Chapter 7 and realizing that the material used to fill a crevasse would be snow and ice native to the surrounding area, the effects of altering the terrain to develop and implement a traverse capability are expected to be localized along the route and virtually negligible. The nature and extent of any additional physical disturbances that may result from the use of established traverse routes by others (e.g., nongovernmental organizations) may include the use of temporary camps, development of spurs to the route, and the risk of additional hazardous materials releases.

Other types of environmental disturbances that would be expected to occur as a result of the proposed action include the generation of noise and vibrations from the traverse vehicles, generators, and ancillary equipment. Individually or combined, these disturbances are not expected to result in a significant impact because they would occur in extremely remote inland areas, with no receptors, and no ecologically sensitive wildlife habitats and be extremely transitory.

6.3.2 Air Emissions

During the use of the proposed USAP traverse capabilities, emissions from the combustion of petroleum hydrocarbon fuels will be released to the atmosphere. These emissions will originate from the internal combustion engines on tractors used to haul trailers, generators and heaters operated for personnel support, and ancillary equipment such as snowmobiles. Table 6-1 presents the estimated annual operating time and fuel usage for equipment used to transport re-supply cargo to the South Pole from McMurdo Station.

Table 6-1. Projected Annual Operating Time and Fuel Usage for Re-supply Traverse Activities

Equipment	Total Operating Time (hours) [1]	Fuel Combustion Rate (L/hr) [2]	Annual Fuel Consumption (liters)		Possible Number of Equipment Refuelings [3]
			Diesel	Gasoline	
Alternatives A (Optimal Configuration), D (Minimal Field Support), & E (Existing Routes Only)					
6 - Tractors (Challenger 95)	12,000	58	700,000		1,000
2 - Snowmobiles	1,000	1		1,200	110
1 - Generator (30kW)	2,050	12	25,000		60
2 - Heaters	4,100	1.5	6,600		120

Table 6-1. Projected Annual Operating Time and Fuel Usage for Re-supply Traverse Activities

Equipment	Total Operating Time (hours) [1]	Fuel Combustion Rate (L/hr) [2]	Annual Fuel Consumption (liters)		Possible Number of Equipment Refuelings [3]
			Diesel	Gasoline	
Alternative B (Minimal Frequency)					
6 - Tractors (Challenger 95)	6,000	58	350,000		500
2 - Snowmobiles	500	1		600	55
1 - Generator (30kW)	1,050	12	13,000		30
2 - Heaters	2,050	1.5	3,400		30
Alternative C (Reduced Intensity, Six Swings per Year)					
3 - Tractors (Challenger 95)	6,000	58	350,000		500
2 - Snowmobiles	1,000	1		1,200	110
1 - Generator (30kW)	2,050	12	25,000		60
2 - Heaters	4,100	1.5	6,600		60

Notes:
[1] Includes time for weather delays and equipment maintenance.
[2] Fuel consumption rate for tractors based on *Analysis of McMurdo to South Pole Traverse as a Means to Increase LC-130 Availability in the USAP* (Appendix A); fuel consumption rates for other equipment based on manufacturer specifications.
[3] Assumes tractors are refueled daily and all other equipment is refueled every third day.

Table 6-2 provides practical comparison of the quantity of cargo that may be transported to the Amundsen-Scott Station if transported by traverse and airlift mechanisms.

Table 6-2. Projected Cargo Transport Amounts for Re-supply Traverses

Alternative	Projected Cargo Transported by Traverse (kg per year)	Traverse Fuel Consumed (liters)	Equivalent LC-130 Resources		Potential Fuel Savings (liters)
			No. of Flights	Fuel (liters)	
A (optimal configuration) or E (existing routes only)	800,000	750,000	69	1,200,000	450,000
B (minimal frequency)	400,000	375,000	35	600,000	225,000
C (reduced intensity)	400,000	375,000	35	600,000	225,000
D (minimal field support)	768,000	750,000	67	1,150,000	400,000
F (no action)		0	0	0	0

Using models developed by the U.S. EPA (references 8 and 9), Table 6-3 summarizes the annual emissions for characteristic air pollutants [sulfur oxides (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), exhaust hydrocarbons, and particulate matter (PM)] for each re-supply traverse alternative. Additional air emissions data for other fuel combustion byproducts are provided in Appendix C.

Table 6-3. Annual Air Emissions From Surface Re-supply Traverses

Alternative	Cargo Transported (kg)	Fuel Use (liters)	Fuel Combustion Byproducts (kg)				
			Sulfur Oxides	Nitrogen Oxides	Carbon Monoxide	Exhaust Hydro-carbons	Particulates
A, D, or E	800,000	750,000	49.8	27.0	9.9	1.4	2.2
B	400,000	375,000	25.6	13.7	5.0	0.7	1.1
C	400,000	375,000	47.8	21.7	8.2	1.1	1.9
LC-130 Aircraft Transporting an Equivalent Quantity of Cargo							
A, D, or E	800,000	1,200,000	1,358	10,734	7,208	3,210	2,953
B or C	400,000	600,000	688	5,440	3,653	1,627	1,496

Exhaust emissions resulting from the combustion of fuel during re-supply traverse activities are expected to be transitory and dissipate as minor concentrations along the 2000-km traverse route. The exhaust emissions are not expected to adversely impact human health or the environment. For comparison, McMurdo Station, which uses 10 times more fuel in one year than the optimally configured traverse (Alternative A), was monitored continuously and found to be well below U.S. Ambient Air Quality Standards (reference 10). This suggests that if the stationary sources at McMurdo Station do not adversely impact air quality, the mobile sources on the traverse which use far less fuel would also not create adverse impact air quality. Table 6-3 also presents the estimated air emissions from LC-130 aircraft assuming the aircraft are used to transport the same quantity of cargo as the re-supply traverse. In addition to the fuel savings, traverse activities emit far less quantities of air emissions than LC-130 aircraft.

Although most gaseous fuel combustion emissions dissipate in the atmosphere, carbonaceous aerosols (black carbon) have been detected in Antarctica at very low concentrations downwind of exhaust emission sources (references 11, 12, 13). The potential impacts from the deposition of carbonaceous aerosols and other combustion-related particulates may be realized through alterations of the surface albedo, and modifications of snow and ice chemistry. Because traverse activities are transient, particulate emissions although potentially detectable on a short-term basis are not expected to accumulate to levels which would alter the physical and chemical properties of the terrain and create adverse impacts.

Emissions resulting from the use of explosives (e.g., crevasse mitigation) may also be released to the environment. The primary emission byproducts released from explosives include sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and hydrogen sulfide (H_2S). The impacts resulting from the projected annual use of 10,750 kg of explosives by the USAP were previously evaluated and found not to have more than a minor or transitory effect on the environment (reference 14). During the most recent reporting period for the *USAP Master Permit* (reference 15), a total of 6,400 kg of explosives were used by the USAP throughout Antarctica, yielding emissions of CO (331 kg), NO_x (165 kg), SO_2 (6.37 kg) and H_2S (12.7 kg). If explosives are needed intermittently to support future traverse activities, it is not expected that the total quantity used in the USAP will exceed 10,750 kg per year.

6.3.3 Releases to Snow/Ice Environment

In addition to air emissions, it is expected that other substances may be released to the snow-covered ice sheet as a result of re-supply traverse activities. These releases may include the discharge of wastewater (greywater) in areas where such discharges are permitted and the release of minor materials such as marker flags that cannot be practically retrieved. Accidental releases such as spills to the environment may also occur during traverse activities.

6.3.3.1 Wastewater Discharge

Based on available resources and if practical, wastewater from personnel support operations would be containerized and transported to a supporting USAP facility for disposition. Wastewater would consist of blackwater (i.e., urine and human solid waste) and greywater containing freshwater (made from melted snow and trace residues of soap, food particles, cleaning materials, and personal care products. If needed, wastewater could be discharged to ice pits in snow accumulation areas along the traverse route as allowed by the Antarctic Treaty and the NSF Waste Regulation (45 CFR §671). Optimum wastewater management techniques would be implemented based on available resources (e.g., storage containers, cargo space) and could include a combination of discharge for greywater and containerization for urine and human solid waste. Wastewater would not be discharged to ice-free areas.

Using a model developed for the *USAP Master Permit*, it is estimated that each person at a remote location in Antarctica generates on average 6.88 liters of wastewater (blackwater and greywater) per day. If it is necessary to discharge wastewater in the field, a hole would be dug in the snow at least one meter deep to ensure the waste is isolated from the surrounding environment. The discharged wastewater would become frozen in the ice sheet and thus immobile. Wastewater contains numerous constituents and several general parameters have been used to characterize the pollutant loadings. Pollutant loadings were calculated using per capita loading factors developed for the *USAP Master Permit* (reference 3) and the traverse population. Table 6-4 summarizes the volume of wastewater that may be generated during re-supply traverse activities and associated pollutant loadings.

Table 6-4. Projected Wastewater Generated During Surface Re-supply Traverse Activities

Alternative	**Population (person-days/yr) [1]**	**Wastewater Generated (liters/yr)**	**Possible Number of Discharge Locations per year**
A, D, or E	1,080	7,430	180
B or C	540	3,715	90
Pollutant Loadings (kg/yr) [2]			
Alternative	**Total Suspended Solids**	**Biological Oxygen Demand**	**Ammonia Nitrogen**
A, D, or E	51	108	6
B or C	25	54	3

Notes:
[1] A person-day represents one overnight stay.
[2] Pollutant Loading Factors - Total Suspended Solids (0.047 kg/person-day); Biological Oxygen Demand (0.100 kg/person-day); Ammonia Nitrogen (0.006 kg/person-day)

The combined volume of wastewater projected to be discharged to snow and ice from all field camps operated by the USAP on an annual basis is 45,800 liters (reference 3). If all of the wastewater generated during traverse activities were discharged, the volume released would be a small fraction (i.e., less than 16 percent) of the total volume discharged from all USAP field camps. The impact is therefore expected to be negligible.

6.3.3.2 Other Materials

Minor releases of other materials to the environment are expected to occur occasionally during the implementation of a re-supply traverse. Flags marking the trail, hazards, and other landmarks will remain in the field and will eventually disintegrate or become lost when covered with snow and ice. The occurrence of these releases will be random and their impact is expected to be negligible. Materials released to the environment will be acknowledged each year in the *Annual Report for the USAP Master Permit*.

6.3.3.3 Accidental Releases

Within the Antarctic Treaty, there are a series of operating agreements under which all Antarctic facilities operate including the Protocol on Environmental Protection, which provides guidelines for spill contingency planning. U.S. activities in Antarctica are not only governed by these treaty provisions, but also by direct U.S. regulations as set forth in the Antarctic Conservation Act. These regulations, which require permitting for all activities conducted in Antarctica, also require specific environmental protection practices including spill response and cleanup. Additionally, the USAP voluntarily has adopted pertinent sections of several other U.S.-based regulatory standards as both a practical and "best management practice" approach. These include the National Environmental Policy Act (NEPA), the Resource Conservation and Recovery Act (RCRA), Occupational Safety and Health Agency (OSHA) regulations, and others. Pertinent U.S. environmental legislation specific to oil spills include both U.S. Environmental Protection Agency and U.S. Coast Guard requirements promulgated in response to the Oil Pollution Act of 1990.

Accidental releases may include spills or leaks primarily involving liquids, the unrecoverable loss of equipment, or the dispersal and loss of materials and wastes due to high winds. Since accidental releases are not planned, their frequency, magnitude, and composition cannot be projected in advance. Existing USAP measures will continue to be implemented to prevent accidental releases to the Antarctic environment. In the event of an accidental release, specific procedures and resources will be available to facilitate cleanup and removal of contaminated media (snow, ice) to the maximum extent practical (see Chapter 7, Mitigating Measures). In addition, traverse operations would utilize procedures contained in the *Field Camp Oil Spill Response Guidebook* (reference 16) for spill response actions. All accidental releases would be documented and reported consistent with the requirements of 45 CFR §671 and the *USAP Master Permit*.

During re-supply traverse missions, it is anticipated that fuel and other hazardous materials identified as Designated Pollutants in 45 CFR §671 would be handled or transferred on a daily basis thereby creating a potential for accidental releases. In general, accidental releases occur most often during equipment refueling activities caused by mechanical failures or operator error. During recent proof of concept traverse activities, comprehensive mitigating measures were applied to refueling procedures successfully preventing spills or other accidental releases.

The risk of an accidental release to the Antarctic environment may also be realized from the catastrophic failure of a fuel tank, other storage container, or a vehicle used during a traverse. The containers used on the traverse will be structurally compatible with their contents and able to withstand the physical and environmental conditions to be encountered during the traverse. The USAP will utilize tanks and drums that are suitable for use in Antarctic conditions and compliant with industry standards designed to protect hazardous material containers exposed to handling and transportation stresses.

Secondary containment of all bulk storage containers used on traverse activities will be a priority. The benefits of double walled tanks are well known. For traverse applications, double walled tanks may be less desirable because it is more difficult to reliably detect failures of the inner wall in double wall systems and initiate corrective actions. If possible, the USAP will use containment trays or vessels placed under bulk storage containers to facilitate regular inspections of the tanks and prompt rapid response if a material release or pending container failure is detected.

Containers that may be temporarily stored on the snow surface will be staged in a manner so that they can be effectively located and recovered without damaging the container upon retrieval. Despite the implementation of spill prevention measures, a minimal risk still exists from the failure or loss of a tank, drum, container, or conveyance (hose, pump) or a serious vehicle failure and the subsequent release of hazardous materials to the environment.

If an accidental release occurs, the extent of localized impacts would depend on the type and quantity of material spilled and the surrounding environmental setting. Consistent with established spill response procedures, primary mitigation would involve source control followed by cleanup including the removal of contaminated snow and ice and the use of sorbent materials if the spill occurred on an impermeable surface. Contaminated snow and sorbents would be packed into drums and removed as waste.

If fuel or other liquid Designated Pollutants (lubricant, coolant) are accidentally released to snow covered surfaces, the material would be expected to migrate vertically in the immediate area of the spill, potentially limiting the effectiveness of spill cleanup actions, and resulting in a long-term but localized impact. In locations with a relatively impermeable surface or subsurface layer a more effective cleanup can be achieved, thereby minimizing impacts. Accidental releases involving the catastrophic and irretrievable loss of equipment, fuel, other Designated Pollutants, or wastes in a crevasse would result in a long-term impact unless the condition of the lost materials permit subsequent recovery. Because implementation of the proposed re-supply traverse capability will not involve areas with seasonal sea ice, open water bodies, or local flora and fauna, impacts associated with an accidental release would be expected to remain localized (horizontally, but not vertically in most cases).

6.3.4 Impacts to McMurdo Station Operations

McMurdo Station is the logistical hub for most of the USAP's operations in Antarctica excluding work done on the peninsula supported by Palmer Station and work performed on research vessels. The proposed capability including the expertise and equipment to operate and support re-supply traverse activities would be based at McMurdo Station. McMurdo Station is likely to provide the following types of support:

- Temporary services for traverse personnel (berthing, food service)
- Maintenance and repair of traverse equipment
- Field support (food, emergency equipment and caches, consumable supplies, waste containers)
- Bulk fuels and fuel transfer facilities
- Waste management
- Weather services
- Communications support
- Airlift support (LC-130, Twin Otter, helicopter)
- Medical support

The logistical and personnel resources needed to support the level of re-supply traverse activities described in this environmental review are currently within the capabilities of McMurdo Station operations. The most significant resources available at McMurdo Station that would be needed to support re-supply traverse activities would involve equipment storage and maintenance functions. Advanced resource planning and careful scheduling would be used to avoid or minimize potential conflicts. Field services (e.g., communications, food, fuel caches) that may be needed to support traverse activities are within levels of support currently provided for numerous field activities each year. Environmentally sound fuel transfer infrastructure would need to be further developed as part of preparations for fuel-delivery surface traverses. The support provided by the annual re-supply vessel, annual fuel tanker, and associated cargo and fuel handling resources, airlift capability, and waste management services coordinated by McMurdo Station have sufficient capacity to accommodate the needs of re-supply traverses.

The use of traverse routes by nongovernmental organizations (NGOs) may potentially impact McMurdo Station operations if the Station has to provide search and rescue (SAR) to these parties in emergency situations. Except in emergencies, the U.S. Government does not support private Antarctic expeditions, and the NSF requires full cost recovery when it gives emergency assistance. Antarctic Treaty and Environmental Protocol requirements enforced by an expedition's country of origin are expected to ensure that any such NGO activities will be planned responsibly.

6.3.5 Impacts to Other USAP Operations

In addition to McMurdo Station, the development and implementation of surface traverse capabilities by the USAP could potentially impact other operations in the USAP. Even though McMurdo Station would serve as a central supply hub for proposed traverse operations, it is expected that the traverse equipment and cargo would be staged at Williams Field, a separate facility and aircraft skiway located on the McMurdo Ice Shelf 10 km from McMurdo Station. Facilities located at Williams Field and currently used to support airlift operations would also be expected to be available for staging proposed traverse operations.

Williams Field runway facilities do not typically operate during the first part of the austral summer season. If Williams Field is used to support traverse activities, additional resources may be needed to install and operate the fuel supply hoseline to McMurdo Station and operate the fuel storage and distribution facilities approximately 12 weeks earlier than the current schedule. Since the seasonal sea ice runway would be operational at the same time, these fuel-handling resources would essentially be duplicated. The primary impacts resulting from the concurrent operation of these facilities would be a slight increased risk of fuel spills and the additional fuel management resources needed to simultaneously operate and inspect two systems for spills and leaks.

Operations at the USAP facilities receiving materials transported by surface re-supply traverse may be impacted differently than if the materials were transported by aircraft. For example, at the Amundsen-Scott Station, the quantity of cargo that may arrive via a single traverse would greatly exceed the quantity of cargo that could be delivered by several aircraft in a day. This impact would be offset by the fact that the cargo would be handled by the traverse crew instead of Station personnel and the cargo itself would be much easier to handle since it would not have to be unloaded from aircraft whose engines must remaining running while at the South Pole.

6.3.6 Impacts to Scientific Research in the USAP

The use of surface traverse capabilities in Antarctica will have localized physical impacts such as terrain alteration and air emissions affecting the snow and ice along the traverse route itself. The route of any traverse will be carefully selected to avoid areas of ongoing scientific research and Antarctic Specially Protected Areas (ASPAs), or other sensitive areas controlled by management plans. Major traverse routes in use will be thoroughly documented so that future scientific research may be designed to avoid these areas if potential conflicts are anticipated. If a new traverse route is planned which comes in proximity to a sensitive area, a supplemental review will be performed of the proposed action to identify potential receptors and mitigating measures including redirection of the traverse route.

Physical disturbances and environmental releases such as air emissions and accidental spills resulting from traverse operations have the potential to affect various types of research such as air monitoring, seismic studies, or investigations requiring undisturbed snow and ice. Traverse activities and surface-based surveys will be planned to avoid areas known to be used for these purposes, but trace levels of residues from traverse operations may be permanently deposited in the snow and ice along the route. Past and active traverse routes used by the USAP would be delineated and mapped so that future scientific research efforts that require undisturbed snow or ice can be designed to avoid potential conflicts in areas of known disturbance.

The availability of surface traverse capabilities in the USAP will yield a positive impact to scientific research by providing an alternative cargo transport mechanism to supplement airlift resources particularly for the transport of large or heavy cargo items. For example, the use of traverse capabilities to re-supply the Amundsen-Scott Station would allow the transport of large instruments, such as telescopes or towers that cannot be performed using current airlift resources. In addition, the balanced use of airlift and traverse transport mechanisms will free-up limited airlift resources thereby allowing aircraft to become more available to support new research opportunities.

6.3.7 Impacts to Social Conditions

As described in Section 2, there is a long and diverse history of the use of surface traverses by numerous nations in Antarctica for re-supply and science-related purposes. The development and use of a traverse capability by the USAP would add to this history and potentially impact some of the social conditions in Antarctica.

The use of a surface traverse route and the associated presence of human activity will result in physical disturbances to the terrain which may be considered a temporary and localized visual impact to the aesthetic and wilderness values of the Antarctic landscape. This type of visual impact may be most noticeable following the performance of re-supply traverses which may use groomed, marked routes on a reoccurring and periodic basis. In general, these physical disturbances would tend to disappear gradually depending on the frequency the route is used and as snow accumulates.

Several decades ago, the United States largely abandoned the use of surface traverses favoring aircraft transport. The U.S. has realized that there is not a single mode of personnel and cargo transport which is effective for every type of cargo. The USAP intends to develop an effective traverse capability to supplement the existing airlift resources and rejoin the Antarctic Treaty nations who continue to use this effective mode of transport.

If the USAP establishes one or more traverse routes, there is the potential that they may be used by other nations or NGOs. The extended use of these routes could increase the environmental impacts. As with all other locations within Antarctica, there is no ownership of the land and all entities are free to operate ships, aircraft, and surface vehicles for peaceful purposes. While the presence of an established traverse route could be used to support operations, research, exploration, or tourism by non-USAP entities, there are many risks which must be managed in order for the venture to be successful. Surface field operations in Antarctica must plan for the physical obstacles, environmental conditions, and logistical support needs that must be considered if a traverse route is to be used. Preparations to meet these challenges will require significant time and resources to ensure success. In addition to the required resources, the length of travel time needed to traverse long distances, combined with the relatively short austral summer season may serve to discourage entities from using established traverse routes except as needed to support ongoing operations or scientific research.

All actions proposed by Antarctica Treaty signatory nations are subject to the environmental impact assessment requirements of the Protocol on Environmental Protection to the Antarctic Treaty (Protocol). Specifically, the assessment procedures set out in Annex I, Environmental Impact Assessment, must be applied to decisions about any activities undertaken in Antarctica pursuant to scientific research programs, tourism and all other governmental and non-governmental activities for which advance notice is required under Article VII (5) of the Antarctic Treaty. Annex I describes the different impact categories as well as the requirements for document circulation and review.

In 1994 the Treaty countries made further recommendations on tourism and non-government activities. This "Guidance for Visitors to the Antarctic" is intended to help visitors become aware of their responsibilities under the treaty and protocol. The document concerns the protection of Antarctic wildlife and protected areas, the respecting of scientific research, personal safety and impact on the environment. Regulations have also been written for the organizers of tourist and private ventures that are subject to U.S. legislation and require prior notification of the trip to the organizer's national authorities, assessment of potential environmental impacts, the ability to cope with environmental emergencies such as oil spills, self-sufficiency, the proper disposal of wastes and respect for the Antarctic environment and research activities. The guidelines outline detailed procedures to be followed during the planning of the trip, when in the Antarctic Treaty area and on completion of the trip.

6.3.8 Indirect or Second Order Impacts

The primary indirect or second order impact that may be realized as a result of the development and implementation of surface traverse capabilities is related to a reduction in the level of airlift resources currently allocated to support re-supply missions. As shown in the example to use traverse capabilities to supplement current airlift resources for the re-supply of the Amundsen-Scott Station, approximately 70 LC-130 flights representing 400 flight hours may become available through the use of surface traverse capabilities (Alternatives A and E). The USAP could use these airlift resources to enhance support to existing or spawn new research opportunities in Antarctica while providing a more efficient mode of transport for certain types of cargo.

As previously described, the existing logistical and personnel support systems of the USAP at McMurdo Station have sufficient capacity to support the efforts associated with the development and use of surface traverse capabilities without significant conflicts.

6.3.9 Cumulative Impacts

A cumulative impact is the combined impact of past and present activities as well as those which may occur in the foreseeable future. The primary cumulative impacts that will result from the use of traverse capabilities by the USAP would be associated with repeated use of traverses for re-supply purposes. Potential cumulative impacts would result from the repeated deposition of particulate exhaust emissions on snow and ice surfaces and the release of wastewater and other substances in the environment. Although these impacts would be highly localized to the traverse route and therefore minor, the effects would be persistent and more than transitory. The cumulative impacts would remain relatively isolated and would not be expected to adversely impact human health or the Antarctic environment. Similarly, the use of surface traverse capabilities would not be significant when combined with the impacts from other activities typically performed at various field locations in Antarctica.

6.3.10 Unavoidable Impacts

Unavoidable impacts are those which are inherent to the proposed action and cannot be fully mitigated or eliminated if the action is completed. Unavoidable impacts resulting from the use of surface traverse capabilities include the physical disturbance of the surface along the traverse route, the release of fuel combustion byproducts from the operation of traverse and personnel support equipment, and the temporary occupation of wilderness areas.

6.4 Environmental Impacts Associated with Science Traverses

To identify and evaluate potential impacts associated with scientific traverses and surface-based surveys, the International Trans Antarctic Scientific Expedition (ITASE) traverse recently conducted by the USAP between Byrd Surface Camp and the South Pole was selected as a representative example of a typical scientific traverse. The analysis of environmental impacts focuses on physical disturbance, air quality, releases to the environment and impacts to McMurdo Station operations, other USAP facilities, scientific research, and social conditions in the Antarctic. Additional impacts that are addressed include indirect or second order impacts, cumulative impacts, and unavoidable impacts.

6.4.1 Physical Disturbance to Snow/Ice Environment

The nature and extent of science traverse and surface-based survey activities will be defined by the intended research and will generally involve the physical disturbance of snow and ice areas. Areas characterized in this CEE and potentially impacted by science-related traverse activities include the Ross Ice Shelf, Transantarctic Mountains, and Polar Plateau. Research activities conducted in other environmental settings (e.g., coastal areas, dry land) will require supplemental environmental review.

It is expected that science-related traverses would typically proceed on undeveloped routes in the areas intended for the research but could also use routes established by other entities (i.e., nations) for other purposes. Because science-related traverses are not expected to be used repeatedly, a science traverse would probably try to circumnavigate and avoid crevasses as opposed to filling them for mitigation. Should crevasse mitigation be necessary for safe passage, explosives may be used to expose the crevasse and native snow and ice would be used to fill the void. The effects associated with filling crevasses (i.e., terrain alteration) are expected to be negligible and localized to the traverse route.

Other types of environmental disturbances that would be expected to occur as a result of the proposed action include the generation of noise and vibrations from the traverse vehicles, generators, and ancillary equipment. Individually or combined, these disturbances are not expected to result in a significant impact because they would occur in extremely remote inland areas, with no receptors, and no ecologically sensitive wildlife habitats.

6.4.2 Air Emissions

During the use of USAP traverse capabilities for science-related applications, emissions from the combustion of petroleum hydrocarbon fuels will be released to the atmosphere. These emissions will originate from the internal combustion engines on tractors used to haul trailers, generators and heaters operated for personnel support, and ancillary equipment such as snowmobiles. Table 6-5 presents the estimated operating time and fuel consumption amounts for equipment used to perform a typical scientific traverse.

Table 6-5. Projected Operating Time and Fuel Consumption for a Typical Science-related Traverse

Equipment	Annual Operating Time (hours) [1]	Fuel Combustion Rate (L/hr)[2]	Annual Fuel Consumption (liters)	
			Diesel	Gasoline
2 - Tractors (Challenger 55)	1,000	30	30,000	0
2 - Snowmobiles	500	1	0	575
1 - Generator (30kW combined capacity)	500	12	6,000	0
4 – Heaters	2,000	1.5	3,000	0

Notes:
[1] Days of operation includes time weather delays and equipment maintenance.
[2] Fuel consumption rate for tractors based on data presented in the *US ITASE 2002-2003 Field Report* (Appendix B). Fuel consumption rates for other equipment based on manufacturer specifications and average operating conditions.

Table 6-6 summarizes the annual emissions for characteristic air pollutant emissions (i.e., sulfur oxides, nitrogen oxides, carbon monoxide, exhaust hydrocarbons, and particulate matter) for each science-related traverse performed. Additional air emissions data for other fuel combustion byproducts are provided in Appendix C.

Table 6-6. Air Emissions From a Typical Science-related Traverse

Fuel Use (liters)	Fuel Combustion Byproducts (kg)				
	Sulfur Oxides	Nitrogen Oxides	Carbon Monoxide	Exhaust Hydrocarbons	Particulates
40,000	21	7.8	3.1	0.4	0.8

Exhaust emissions resulting from the combustion of fuel during relatively short-term scientific traverse activities are expected to be transitory and dissipate as the traverse proceeds along the route. The exhaust emissions are not expected to adversely impact human health or the environment. For comparison, fuel combustion emissions at McMurdo Station, the USAP's largest station and logistical support hub, were measured and determined to have no significant impact on air quality (reference 10). Carbonaceous aerosols (black carbon) have also been measured downwind of exhaust emissions sources in Antarctica (references 11, 12, 13) and, while detected at low concentrations, were found to have no significant impact on the surface albedo or snow and ice chemistry. These observations suggest that because science-related traverse activities use far less fuel than stations operations, gaseous and particulate emissions although potentially detectable are not expected to accumulate to levels which would alter the physical and chemical properties of the terrain or create adverse impacts.

Emissions (SO_2, NO_x, CO, and H_2S) from explosives used to mitigate crevasse hazards during scientific traverses or surface-based surveys may also be released to the environment. It is highly unlikely that explosives will be needed since explosives were not use during four recent years of ITASE traverse activities. If explosives are needed, it is not expected that the quantity of explosives used would be significant.

6.4.3 Releases to Snow/Ice Environment

In addition to air emissions, it is expected that other substances may be released to the snow-covered ice sheet as a result of re-supply traverse activities. These releases may include the discharge of wastewater (greywater) in areas where such discharges are permitted and the release of minor materials such as marker flags that cannot be practically retrieved. Accidental releases such as spills to the environment potentially could also occur during traverse activities.

6.4.3.1 Wastewater Discharge

Based on available resources and if practical, wastewater from personnel support operations would be containerized and transported to a supporting USAP facility for disposition. Wastewater would consist of blackwater (i.e., urine and human solid waste) and greywater containing freshwater made from melted snow and trace residues of soap, food particles, cleaning materials, and personal care products. If needed, wastewater could be discharged to ice pits in snow accumulation areas along the traverse route as allowed by the Antarctic Treaty and the NSF Waste Regulation (45 CFR §671). Optimum wastewater management techniques would be implemented based on available resources (e.g., storage containers, cargo space) and could include a combination of discharge for greywater and containerization for urine and human solid waste. Wastewater would not be discharged to ice-free areas.

Using a model developed for the *USAP Master Permit*, it is estimated that each person at a remote location in Antarctica generates on average 6.88 liters of wastewater (blackwater and greywater) per day. If it is necessary to discharge wastewater in the field, a hole would be dug in the snow at least one meter deep to ensure the waste is isolated from the surrounding environment. The discharged wastewater would become frozen in the ice sheet and immobile. Table 6-7 provides estimates of the volume of wastewater that may be generated and discharged and associated pollutant loadings.

Table 6-7. Projected Wastewater Generated During a Typical Science-related Traverse

Population (person-days) [1]	**Wastewater Generation Volume (liters)**	**Possible Number of Discharge Locations per year**
520	3,600	40
Pollutant Loadings [2]		
Total Suspended Solids (kg)	**Biological Oxygen Demand (kg)**	**Ammonia Nitrogen (kg)**
25	50	3

Notes: [1] A person-day represents one overnight stay
[2] Pollutant Loading Factors: Total Suspended Solids (0.047 kg/person-day); Biological Oxygen Demand (0.100 kg/person-day); Ammonia Nitrogen (0.006 kg/person-day)

6.4.3.2 Other Materials

Minor releases of materials to the environment are expected to occur occasionally during the implementation of a re-supply traverse. Flags marking the trail, hazards, and other landmarks will remain in the field and will eventually disintegrate or become lost when covered with snow and ice. Other types of traverse-related materials that may be released on a random basis include cables or anchoring devices. The type and quantity of these releases will be dependent on the type of field research activities performed. Supplemental environmental reviews will be performed for science-related activities which involve the deployment of specialized pieces of equipment which will not or can not be retrieved. Materials released to the environment will be acknowledged each year in the *Annual Report for the USAP Master Permit*.

6.4.3.3 Accidental Releases

Within the Antarctic Treaty, there are a series of operating agreements under which all Antarctic facilities operate including the Protocol on Environmental Protection, which provides guidelines for spill contingency planning. U.S. activities in Antarctica are not only governed by these treaty provisions, but also by direct U.S. regulations as set forth in the Antarctic Conservation Act. These regulations, which require permitting for all activities conducted in Antarctica, also require specific environmental protection practices including spill response and cleanup. Additionally, the USAP voluntarily has adopted pertinent sections of several other U.S.-based regulatory standards as both a practical and “best management practice” approach. These include the National Environmental Policy Act (NEPA), the Resource Conservation and Recovery Act (RCRA), Occupational Safety and Health Agency (OSHA) regulations, and others. Pertinent U.S. environmental legislation specific to oil spills include both U.S. Environmental Protection Agency and U.S. Coast Guard requirements promulgated in response to the Oil Pollution Act of 1990.

Accidental releases may include spills or leaks primarily involving liquids, the unrecoverable loss of equipment, or the dispersal and loss of materials and wastes due to high winds. Since accidental releases are not planned, their frequency, magnitude, and composition cannot be projected in advance. Existing USAP measures will continue to be implemented to prevent accidental releases to the Antarctic environment. In the event of an accidental release, specific procedures and resources will be available to facilitate cleanup and removal of contaminated media (snow, ice) to the maximum extent practical (see Chapter 7, Mitigating Measures). In addition, traverse operations would utilize procedures contained in the *Field Camp Oil Spill Response Guidebook* (reference 16) for spill response actions. All accidental releases would be documented and reported consistent with the requirements of 45 CFR §671 and the *USAP Master Permit*.

During science-related traverse missions, it is anticipated that fuel and other hazardous materials identified as Designated Pollutants in 45 CFR §671 would be handled or transferred on a daily basis thereby creating a potential for accidental releases. In general, accidental releases occur most often during equipment refueling activities caused by mechanical failures or operator error. During recent ITASE traverses performed by the USAP, comprehensive mitigating measures were applied to refueling procedures successfully preventing spills or other accidental releases.

The risk of an accidental release to the Antarctic environment may also be realized from the catastrophic failure of a fuel tank, other storage container, or a vehicle used during a traverse. Results from the analysis of previous spills and container failures in the USAP will be used to design and specify equipment and procedures which minimizes the risk of releases during surface traverse activities. The containers used for traverse activities will be structurally compatible with their contents and able to withstand the physical and environmental (e.g., temperature) conditions to be encountered during the traverse. Secondary containment of all bulk storage containers used on traverse activities will be a priority. If possible, the USAP will use containment trays or vessels placed under bulk storage containers to facilitate regular inspections of the tanks and prompt rapid response if a release or pending failure is detected. If containment structures are not feasible, double walls tanks may be used.

It is expected that either full or empty mobile storage tanks or drums used to transport fuel and other bulk liquids needed for the operation of the traverse equipment may be stored on a traverse route. Containers temporarily stored on the snow surface will be staged in a manner so that they can be effectively located and recovered without damaging the container upon retrieval.

Since the equipment used to conduct a science-related traverse may not be configured to transport all of the fuel and other consumable supplies needed for an extended traverse mission, airlift support may be used to periodically re-supply the traverse. Re-supply may occur directly from LC-130 aircraft which land near the traverse equipment or through the retrieval of supplies airdropped or placed in field caches along the traverse route. To minimize the risk of accidental releases resulting from the use of temporary field caches of fuel or other materials, the materials will be placed on the snow surface in a manner to protect the contents and facilitate effective retrieval without damage to the container.

Airdropped materials may be accidentally released to the environment if the containers are damaged or land in conditions where the materials are lost and cannot be recovered. During the 2002-2003 ITASE traverse activities, a total of 96 drums of fuel on 24 pallets were airdropped at four sites along the traverse route. Although the airdrop parachutes failed on five of the 24 deployments causing the pallets to be buried in the snow, all drums were recovered intact with no discernible loss of fuel.

Despite the implementation of spill prevention measures, a minimal risk still exists from the failure or loss of a tank, drum, container, or conveyance (hose, pump) or a serious vehicle or airdrop failure and the subsequent release of hazardous materials to the environment. If an accidental release occurs, the extent of localized impacts would depend on the type and quantity of material spilled and the surrounding environmental setting. Consistent with established spill response procedures, primary mitigation would involve source control followed by cleanup including the removal of contaminated snow and ice and the use of sorbent materials if the spill occurred on an impermeable surface. Contaminated snow and sorbents would be packed into drums and removed as waste.

If fuel or other liquid Designated Pollutants (lubricant, coolant) are accidentally released to snow covered surfaces, the material would be expected to migrate vertically in the immediate area of the spill, potentially limiting the effectiveness of spill cleanup actions, and resulting in a long-term but localized impact. In locations with a relatively impermeable surface or subsurface layer a more effective cleanup can be achieved, thereby minimizing impacts. Accidental releases involving the catastrophic and irretrievable loss of equipment, fuel, other Designated Pollutants, or wastes in a crevasse would result in a long-term impact unless the condition of the lost materials permit subsequent recovery. Because implementation of science-related traverses addressed by this environmental review will not involve areas with seasonal sea ice, open water bodies, or local flora and fauna, impacts associated with an accidental release would be expected to remain localized (horizontally, but not vertically in most cases).

6.4.4 Impacts to McMurdo Station Operations

McMurdo Station is the logistical hub for most of the USAP's operations in Antarctica excluding work done on the peninsula supported by Palmer Station and work performed on research vessels. The proposed capability including the expertise and equipment is an enhancement of the resources that

McMurdo Station has provided in the past to support science-related traverse activities. McMurdo Station is likely to provide the following types of support:

- Temporary services for traverse personnel (berthing, food service)
- Maintenance and repair of traverse equipment
- Field support (food, emergency equipment and caches, consumable supplies, waste containers)
- Bulk fuels
- Waste management
- Weather services
- Communications support
- Airlift support (LC-130, Twin Otter, helicopter)
- Medical support

The logistical and personnel resources needed to support the level of science-related traverse activities described in this environmental review are currently within the capabilities of McMurdo Station operations. The most significant resources available at McMurdo Station that would be needed to support any type of traverse activities would involve equipment storage and maintenance functions. Advanced resource planning and careful scheduling would be used to avoid or minimize potential conflicts. Field services (e.g., communications, food, fuel caches) that may be needed to support traverse activities are within levels of support currently provided for numerous field activities each year.

6.4.5 Impacts to Other USAP Operations

It is anticipated that McMurdo Station will serve as the central supply hub for most USAP science-related traverse activities. Depending on the nature of the intended research, other facilities (e.g., Amundsen-Scott Station, Byrd Surface Camp) may be used as supply depots or locations where equipment may be temporarily stored. The stops at these facilities would be integral to the research and planned accordingly, therefore no adverse impacts to facility operations would be expected.

6.4.6 Impacts to Scientific Research in the USAP

The use of surface traverse capabilities in Antarctica will have localized physical impacts (i.e., terrain alteration, air emissions) on the snow and ice along the traverse route itself. The route of any traverse will be carefully selected to avoid areas of ongoing scientific research and Antarctic Specially Protected Areas (ASPAs), or other sensitive areas controlled by management plans. Traverse routes in use will be thoroughly documented so that future scientific research may be designed to avoid these areas if potential conflicts are anticipated. If a new traverse route is planned which comes in proximity to a sensitive area (e.g., ASPA), a supplemental review will be performed of the proposed action to identify potential receptors and mitigating measures including redirection of the traverse route.

Physical disturbances and environmental releases (e.g., air emissions, accidental spills) resulting from traverse operations have the potential to affect various types of research such as air monitoring, seismic studies, or investigations requiring undisturbed snow and ice. Traverse activities and surface-based surveys will be planned to avoid areas known to be used for these purposes, but trace levels of residues from traverse operations may be permanently deposited in the snow and ice along the route. Past and active traverse routes used by the USAP would be delineated and mapped so that future scientific research efforts that require undisturbed snow or ice can be designed to avoid potential conflicts in areas of known disturbance.

The availability of surface traverse capabilities in the USAP will yield a positive impact to scientific research by providing an alternative cargo transport mechanism to supplement airlift resources particularly for the transport of large or heavy cargo items. For example, the use of traverse capabilities to re-supply the Amundsen-Scott Station would allow the transport of large instruments, such as telescopes or towers that cannot be performed using current airlift resources. In addition, the balanced use of airlift and traverse transport mechanisms will decrease the reliance on aircraft thereby allowing the USAP airlift resources to become available for other purposes.

Surface traverse capabilities will also provide a platform to potentially supplement a greater variety of scientific research projects or advanced surface-based survey activities in Antarctica. As documented in the recent ITASE experience, the availability of surface traverse capabilities can provide researchers with a mobile, interactive venue for research along geographical corridors similar to that afforded by large field camps but without the limitations of fixed camp-based data collection efforts. For example, conducting traverse-based research on a routine basis will allow the high-resolution sampling of glaciological parameters (in particular, accurate snow accumulation and temperature measurements), subglacial geology (through high resolution seismics), meteorology, climate sciences, and aeronomy. It is expected that the availability of surface traverse resources may result in a paradigm shift in the scientific community, and that scientists will propose innovative investigations that cannot yet be predicted.

6.4.7 Impacts to Social Conditions

As described in Chapter 2, there is a long and diverse history of the use of surface traverses by numerous nations in Antarctica for science-related purposes. The development and use of a traverse capability by the USAP would add to this history and potentially impact some of the social conditions in Antarctica.

The use of surface traverses to conduct surface-based scientific research and the associated presence of human activity will result in physical disturbances to the terrain which may be considered a temporary and localized visual impact to the aesthetic and wilderness values of the Antarctic landscape. Visual impacts resulting from science-related traverses or surface-based surveys would be expected to be barely noticeable, since the route may be traveled only once or much less frequently than re-supply traverse missions. The physical disturbances would be expected to disappear gradually after the traverse is completed as snow continues to accumulate along the traverse route.

For the past several decades, the United States preferred the use of aircraft resources to support scientific activities at field sites and largely abandoned the use of surface traverses. The U.S. has realized that for some types of research there is a developing need to collect data on smaller distance scales which may not be effectively supported solely by airlift resources. The USAP intends to develop traverse capabilities to effectively provide a support mechanism for surface-based research and rejoin the Antarctic Treaty nations who continue to use these resources as an integral component of scientific studies.

6.4.8 Indirect or Second Order Impacts

The use of surface traverse capabilities by the USAP for science-related research purposes is not anticipated to result in any significant indirect or second order impacts. The scope of this CEE focuses on the use of traverse equipment to provide a mobile platform for the performance of research investigations. Potential impacts associated with the research methods proposed for use on science-related traverse missions will undergo separate environmental reviews.

6.4.9 Cumulative Impacts

A cumulative impact is the combined impact of past and present activities as well as those which may occur in the foreseeable future. Similar to other scientific research activities performed by the USAP each year, science-related traverse activities or surface-based surveys will, by design, generally take place in undisturbed areas on a short-term basis. Therefore, no significant cumulative impacts are expected from these activities.

6.4.10 Unavoidable Impacts

Unavoidable impacts are those which are inherent to the proposed action and cannot be fully mitigated or eliminated if the action is completed. Unavoidable impacts resulting from the use of surface traverse capabilities include the physical disturbance of the surface along the traverse route, the release of fuel combustion byproducts from the operation of traverse and personnel support equipment, and the temporary occupation of wilderness areas.

6.5 Summary of Impacts

The potential impacts from the use of surface traverse capabilities for either re-supply or scientific purposes have been identified and evaluated consistent with the Guidelines for Environmental Impact Assessment in Antarctica (reference 17). Table 6-8 summarizes the criteria used to evaluate the significance of the potential impacts relative to the extent, duration, intensity, and reversibility of each activity as well as the probability of its occurrence. Table 6-9 summarizes all potential environmental and operational impacts that may be caused by re-supply traverse activities, and Table 6-10 summarizes the impacts that may be caused by scientific traverses and surface-based surveys.

Table 6-8. Criteria for Assessment of Potential Impacts on the Environment

		Criteria of Assessment			
Impact	**Environment**	**Low (L)**	**Medium (M)**	**High (H)**	**Very High (VH)**
EXTENT	*Air* *Snow/ice* *Terrestrial* *Aesthetic & Wilderness*	*Local extent* Action results in an isolated impact and confined to the site where the action occurred	*Partial extent* Action is isolated but possibly may migrate and affect surrounding area	*Major extent* Initially the action is isolated but likely to migrate and affect surrounding environment	*Entire extent* Large-scale impact along the entire traverse; migration will cause further impact
DURATION	*Air* *Snow/ice* *Terrestrial* *Aesthetic & Wilderness*	*Short term* Several weeks to one season; short compared to natural processes	*Medium term* Several seasons to several years	*Long term* Decades	*Permanent* Environment will suffer permanent impact
INTENSITY	*Air* *Snow/ice* *Terrestrial* *Aesthetic & Wilderness*	*Minimal Affect* Natural functions and processes of the environment are not affected	*Affected* Natural functions or processes of the environment are affected, but on a moderate or short-term basis	*High* Natural functions or processes of the environment are affected and changed	*Extensive* Natural functions or processes of the environment are fully disrupted and adversely impacted
REVERS-IBILITY	*Air* *Snow/ice* *Terrestrial* *Aesthetic & Wilderness*	*Reversible* Impacts are reversible; the affected environment will return to its initial state	*Affected* Impacts are essentially irreversible but are isolated and do not significantly interact with the surrounding environment	*High* Impacts are irreversible and may alter the surrounding environment over the long term	*Irreversible* Impacts will result in permanent changes and adversely affect the environment
PROB-ABILITY		Impact should not occur under normal traverse operations and conditions	Impact possible but unlikely	Impact likely or probable to occur during traverse operations	Impact inherent to the proposed action and unavoidable

Table 6-9. Summary of Environmental and Operational Impacts from Re-supply Traverses

Activity	Duration of Activity	Output	Environmental and Operational Impacts (legend Table 6-8)						Mitigating Measures (Table 7-1) [1]
			Affected Environment	Extent	Duration	Intensity	Reversibility	Probability	
Crevasse Mitigation	As Needed (mitigation only required during initial route development)	Emissions from the use of explosives	Air	L	L	L	L	H	2.2
			Snow/Ice	L	L	L	M	H	2.2
		Physical Disturbance– terrain alteration	Snow/Ice	L	L	L	M	H	2.2
		Physical Disturbance - noise, vibration, EM radiation	Snow/Ice	L	L	L	L	M	2.2
			Other Research Projects	L	L	M	L	L	2.2 7.1 - 7.2
Operation of Tractors	Daily, 120 days per austral summer	Exhaust Emissions	Air	L	L	L	L	VH	3.1 - 3.2
			Snow/Ice	L	H	L	M	VH	3.1 - 3.2
		Physical Disturbance – terrain alteration	Snow/Ice	L	L	L	M	VH	2.1
		Physical Disturbance - noise, vibration, EM radiation	Snow/Ice	L	L	L	L	VH	2.1
			Other Research Projects	L	L	L	L	VH	7.1 - 7.2
			Wildlife	L	L	L	L	L	7.3
		Visual Indicators – markers, groomed surfaces	Aesthetic & Wilderness Values	L	L	L	M	H	8.1 - 8.3
Power Generation	Daily, 120 days per austral summer	Exhaust Emissions	Air	L	L	L	L	VH	3.1 – 3.2
			Snow/Ice	L	M	L	M	VH	3.1 – 3.2

Table 6-9. Summary of Environmental and Operational Impacts from Re-supply Traverses

Activity	Duration of Activity	Output	Environmental and Operational Impacts (legend Table 6-8)						Mitigating Measures (Table 7-1) [1]
			Affected Environment	Extent	Duration	Intensity	Reversibility	Probability	
Personnel Support	As Needed (up to 120 days per austral summer)	Wastewater discharge (no discharge unless waste cannot be containerized)	Snow/Ice	L	L	L	M	M	4.1 – 4.2
Fuel Storage and Handling	Daily, 120 days per austral summer	Accidental Releases/Spills	Snow/Ice	M	M	M	M	M	4.4 – 4.6
Hazardous Materials Management	Daily, 120 days per austral summer	Accidental Releases/Spills	Snow/Ice	L	M	M	M	L	10.1 – 10.4
Waste Management	Daily, 120 days per austral summer	Accidental Releases/Spills	Snow/Ice	L	M	L	M	L	11.1 – 11.3
Field Logistics (field caches, airdrops)	Austral summer (120 days)	Physical Disturbance	Snow/Ice	L	M	L	L	M	4.3
		Release of Irretrievable Materials	Snow/Ice	L	M	L	M	L	4.3, 4.7
		Accidental Releases/Spills	Snow/Ice	L	M	M	M	L	4.3, 4.7
Logistics Support - McMurdo Station	Year-round	Increased equipment maintenance, storage, field ops support	McMurdo Station Operations	L	L	L	M	VH	5.1 – 5.2

Table 6-9. Summary of Environmental and Operational Impacts from Re-supply Traverses

Activity	Duration of Activity	Output	Environmental and Operational Impacts (legend Table 6-8)						Mitigating Measures (Table 7-1) [1]
			Affected Environment	Extent	Duration	Intensity	Reversibility	Probability	
Logistics Support – Other USAP Facilities	Austral summer (120 days)	Equipment and cargo staging, fuel distribution	Facility Operations	L	M	M	L	H	6.1

Note:
[1] Mitigating measures involving traverse design and planning (1.1-1.3) and impact monitoring (9.1-9.5) will be applied to each activity as appropriate.

Table 6-10. Summary of Environmental and Operational Impacts from Typical Science-Related Traverses

Activity	Duration of Activity	Output	Environmental and Operational Impacts (legend Table 6-8)						Mitigating Measures (Table 7-1) [1]
			Affected Environment	Extent	Duration	Intensity	Reversibility	Probability	
Operation of Tractors	As Needed Based on Research (one austral summer or less)	Exhaust Emissions	Air	L	L	L	L	VH	3.1 – 3.2
			Snow/Ice	L	M	L	M	VH	3.1 – 3.2
		Physical Disturbance – terrain alteration	Snow/Ice	L	L	L	M	VH	2.1
		Physical Disturbance - noise, vibration, EM radiation	Snow/Ice	L	L	L	L	VH	2.1
			Other Research Projects	L	L	L	L	VH	7.1 – 7.2
			Wildlife	L	L	L	L	L	7.3
Crevasse Mitigation	As Needed (mitigation will only be used if crevasses cannot be avoided)	Emissions - Explosives	Air	L	L	L	L	L	2.2
			Snow/Ice	L	L	L	M	L	2.2
		Physical Disturbance– terrain alteration	Snow/Ice	L	L	L	M	L	2.2
		Physical Disturbance - noise, vibration, EM radiation	Snow/Ice	L	L	L	L	L	2.2
			Other Research Projects	L	L	L	L	L	2.2 7.1 – 7.2
Power Generation	As Needed Based on Research (one austral summer or less)	Exhaust Emissions	Air	L	L	L	L	H	3.1 – 3.2
			Snow/Ice	L	L	L	M	H	3.1 – 3.2

Table 6-10. Summary of Environmental and Operational Impacts from Typical Science-Related Traverses

Activity	Duration of Activity	Output	Environmental and Operational Impacts (legend Table 6-8)						Mitigating Measures (Table 7-1) [1]
			Affected Environment	Extent	Duration	Intensity	Reversibility	Probability	
Personnel Support	As Needed Based on Research (one austral summer or less)	Wastewater discharge (no discharge unless waste cannot be containerized)	Snow/Ice	L	L	L	M	M	4.1 – 4.2
Fuel Storage and Handling	As Needed Based on Research (one austral summer or less)	Accidental Releases/Spills	Snow/Ice	L	L	M	M	M	4.4 – 4.6
Hazardous Materials Management	Daily, 120 days per austral summer	Accidental Releases/Spills	Snow/Ice	L	L	M	M	L	10.1 – 10.4
Waste Management	As Needed Based on Research (one austral summer or less)	Accidental Releases/Spills	Snow/Ice	L	L	L	M	L	11.1 – 11.3

Table 6-10. Summary of Environmental and Operational Impacts from Typical Science-Related Traverses

Activity	Duration of Activity	Output	Environmental and Operational Impacts (legend Table 6-8)						Mitigating Measures (Table 7-1) [1]
			Affected Environment	Extent	Duration	Intensity	Reversibility	Probability	
Field Logistics (field caches, airdrops)	As Needed Based on Research (one austral summer or less)	Physical Disturbance	Snow/Ice	L	L	L	L	H	4.3
		Release of Irretrievable Materials	Snow/Ice	L	L	L	M	L	4.3, 4.7
		Accidental Releases/Spills	Snow/Ice	L	L	M	M	M	4.3, 4.7
Logistics Support - McMurdo Station	As Needed Based on Research	Increased Equipment maintenance, storage, field ops support	McMurdo Station Operations	L	L	L	M	H	5.1 – 5.2
Logistics Support – Other USAP Facilities	As Needed Based on Research (one austral summer or less)	Equipment and cargo staging, fuel distribution	Facility Operations	L	L	L	L	L	6.1

Note:
[1] Mitigating measures involving traverse design and planning (1.1-1.3) and impact monitoring (9.1-9.5) will be applied to each activity as appropriate.

7.0 MITIGATION OF ENVIRONMENTAL IMPACTS AND MONITORING

7.1 Introduction

Mitigating measures represent specific actions that may be taken to reduce or avoid potentially adverse impacts to the environment or related impacts to the USAP. This chapter of the Comprehensive Environmental Evaluation (CEE) describes measures that will be taken or are under consideration to mitigate (i.e., reduce or avoid) impacts to the environment and USAP operations resulting from the development and use of surface traverse capabilities. This section also describes the activities that will be conducted to monitor and document impacts of traverses that may be performed as a result of the proposed action and, if appropriate, trigger corrective action.

7.2 Mitigating Measures

A list of mitigating measures applicable to re-supply and science-related traverses and surface-based surveys is presented in Table 7-1. The mitigating measures relate to the potential impacts discussed in Chapter 6, and include a series of measures that would be implemented during the planning and design phases of traverse activities.

The mitigating measures have been designed to be flexible and address a variety of conditions that may be encountered. Some of the proposed mitigating measures have already been incorporated into various field procedures used by the USAP. In addition, Table 7-1 includes mitigating measures which are applicable to the environmental requirements of the *USAP Master Permit* such as the management of Designated Pollutants (i.e., hazardous materials), the management and disposition of all hazardous and nonhazardous wastes, the control of substances released to the environment, and the monitoring of environmental conditions and impacts.

The most significant series of mitigating measures are initiated during the planning and preparation stages of a traverse or surface-based survey activity and well before the actual field work is underway. Frequently more than a year in advance, the specific goals of a traverse are compiled, resource specifications and procedures needed to accomplish the mission are developed, equipment is procured and staged, and personnel are trained. During the planning and preparation stages, features are built into the design of the proposed traverse activity to ensure that the resources needed to conduct the traverse and mitigate potential impacts are appropriately available. Organizational impacts related to USAP facilities that may be involved in the proposed action may be effectively mitigated through advanced planning, scheduling, and allocation of resources and facilities.

Prior to the initiation of traverse activities, the USAP will develop an impact monitoring strategy to detect, if any, temporal and spatial changes caused by traverse operations. Environmental impact assessment would be conducted during all phases of operations, particularly during the planning phases to ensure that resources are adequately available to support mitigating measures and minimize environmental impacts. Through a regular process the USAP performs a preliminary review of proposed actions, including operations and research activities, to identify potential environmental impacts and to identify those impacts which have not been previously evaluated in environmental documents such as Records of Environmental Review (ROERs), Initial Environmental Evaluations (IEEs), and Comprehensive Environmental Evaluations (CEEs). Where warranted, further environmental evaluation, development of specific mitigating measures and subsequent documentation is performed. Proposed activities involving surface traverses will also undergo this review, and activities in a different environmental setting or having the potential to yield impacts that have not been identified in this CEE will be subject to a supplemental environmental evaluation.

Table 7-1. Summary of Mitigating Measures

Aspect	Mitigating Measure
Traverse Design and Planning (1.0)	1.1 Traverse route: The surface route selected for traverse operations should be designed to meet the goals of the mission (re-supply, scientific research) and minimize disturbances to the environment • The route should be located in areas where traverse operations and unplanned events such as accidental releases will not adversely impact the sensitive regions of the surrounding environment. Maintain a minimum distance of 250 meters from Antarctic Specially Protected Areas (ASPAs) • If a traverse route is located near a marine environment, ASPA, or other sensitive area, perform a supplemental environmental review to determine the impact of proposed activities
	1.2 Equipment, personnel support resources, and staffing: • The size and number of tractors and trailers/sleds should be appropriate to support the goals of the mission (e.g., re-supply, scientific research) and the environmental conditions (e.g., slope, snow cover) expected during the traverse • The number of personnel assigned to the traverse should be appropriate to meet the goals of the mission and provide an adequate margin of safety • Utilize tractors of proven design and operability characteristics (e.g., maintenance) for surface applications. Tractors should be designed to minimize energy use and production of exhaust emissions • Trailers should be optimally configured for the conditions (e.g., high axles, skis or tracks aligned to those of the lead tractor) • Facilities needed for personnel support and research (e.g., power generation, water production equipment) should be designed to minimize energy use and the production of exhaust emissions. Consider using solar energy or alternative fuels to diesel or gasoline (e.g., propane) • Traverse support equipment (e.g., trailers, personnel modules) should be designed to adequately accommodate the storage of all Designated Pollutants (i.e., hazardous materials) used during the traverse • Traverse support equipment and resources (e.g., containers) should be provided to adequately contain and store all wastes generated during the traverse • Traverse equipment and resources for material transfers (e.g., refueling) should be designed for that purpose and incorporate spill prevention features

Table 7-1. Summary of Mitigating Measures

Aspect	Mitigating Measure
	• Containment trays or vessels will be used to the maximum extent practical to facilitate regular inspections of storage tanks and prompt rapid response if a release or pending container failure is detected. • If external containment structures are not feasible, double walls tanks will be used. • Traverse operating procedures will be designed to include regular inspections (e.g., at least daily) to prompt rapid response if a release or pending container failure is detected. • Traverse support equipment and resources should be provided to enable spill response (e.g., shovels, absorbents, waste drums) and the adequate transfer and containment of material from any damaged or leaking vessel • Utilize procedures contained in the *Field Camp Oil Spill Response Guidebook* (reference 16) for spill response actions and develop supplements as needed to address traverse activities • Provide spill response training to traverse personnel
	1.3 Traverse planning should address the following activities and incorporate additional mitigating measures as appropriate to minimize or avoid impacts to the environment: • Operation of personnel support facilities • Wastewater management • Deployment, use, and decommissioning of field caches • Use of airdrops • Establishment of temporary support camps or stopover location
Physical Disturbance to Snow/Ice Environment (2.0)	2.1 Minimize the amount of terrain alteration or disturbance during operation of personnel support modules by confining activities to areas on or immediately adjacent to the designated traverse route
	2.2 Mitigate crevasse hazards through avoidance, if possible. If physical crevasse hazard mitigation (i.e., filling) is necessary, minimize impacts by: • Limiting the extent of crevasse exposure (i.e., removal of snow bridges) to the length required for safe operations and filling crevasses only to the extent needed to allow safe passage by the traverse equipment • Filling crevasses with surrounding native materials
Air Emissions (3.0)	3.1 Perform regular preventive maintenance on traverse equipment, based on operating hours or other maintenance criteria, to sustain optimal performance and reduce emissions.

Table 7-1. Summary of Mitigating Measures

Aspect	Mitigating Measure
	3.2 Shutdown equipment when not in use to minimize exhaust emissions and utilize engine heaters or equivalent devices to minimize idling of diesel-powered equipment, if practical
Releases to the Snow/Ice Environment (4.0)	4.1 Prohibit wastewater discharges in areas where the ice-flow may terminate in ice-free or blue ice areas of high ablation
	4.2 Limit wastewater discharges to the maximum extent practical and containerize and transport the wastewater to a supporting USAP facility for disposition. In areas where wastewater is discharged: • Limit wastewater discharges to one disposal pit per support module location • Limit wastewater discharges to urine and greywater • If wastewater is to be discharged to an ice sheet, the disposal pit should be at least one m deep to effectively isolate the waste from the surrounding environment • Prohibit the discharge of wastewater on the surface of the terrain • Prohibit discharge of materials containing Designated Pollutants (e.g., chemicals, fuel wastes, lubricants, glycol) • Record the approximate volume of wastewater discharged at each location during support module operations
	4.3 Use of caches or temporary storage areas: • If equipment, materials, or supplies are cached along the traverse route, store the materials in a manner to prevent them from becoming encrusted in snow and ice (e.g. store on pallets) and possibly damaged upon retrieval • Mark and document storage locations to prevent the materials from becoming lost or irretrievable • If airdrops of fuel, materials, or supplies are conducted to support traverse operations, recover all packaging materials (e.g., pallets, parachutes) • Inspect airdropped containers for signs of damage and remediate any spills or leaks immediately
	4.4 Material transfers: • Develop and implement a consistent approach for material transfers (e.g., refueling) and equipment maintenance operations that incorporates spill prevention techniques including the use of containment devices • Drain portable pumps, hoses, and nozzles after use and store in appropriate containment structures • Following all fuel transfers and equipment maintenance operations, inspect adjacent areas for signs of spills or leaks and remediate immediately

Table 7-1. Summary of Mitigating Measures

Aspect	Mitigating Measure
	4.5 Inspect the following daily to detect leaks or damage: • Bulk fuel storage tanks, pipelines, valves, distribution pumps, and hoses • Equipment (generator, heater) tanks, fuel lines • Vehicles (e.g., fuel tanks, oil pans, hydraulic lines, coolant systems) • Storage containers (e.g., drums containing fuel, oil, glycol)
	4.6 Cleanup leaks or spills immediately following their detection to the maximum extent practical, manage resulting contaminated materials as Antarctic Hazardous waste, and report all spills and remedial actions as required by 45 CFR §671
	4.7 Report all lost equipment or instruments as required by 45 CFR §671
Impacts to McMurdo Station Operations (5.0)	5.1 Plan traverse operations and support activities sufficiently in advance to minimize impacts to McMurdo Station operations
	5.2 Conduct traverse staging operations at a location which will not conflict with normal station operations
Impacts to Other USAP Operations (6.0)	6.1 Incorporate scheduled traverse operations into the planning process to ensure affected USAP facility operations and potential conflicts can be adequately identified
Impacts to Scientific Research in the USAP (7.0)	7.1 Prohibit traverse operations in ASPAs unless specifically required for scientific research and conducted in accordance with applicable restrictions
	7.2 Avoid traverse operations near known sensitive scientific areas (e.g., air, seismic monitoring) unless required for scientific research
	7.3 Avoid disturbing wildlife and maintain at a minimum the following separation from animals or receptors: 250 meters (tractors), 150 meters (snowmobiles), 15 meters (foot)
Impacts to Social Conditions (8.0)	8.1 Avoid traverse operations near historic sites and monuments and maintain a minimum vehicle separation of 50 meters when moving
	8.2 Minimize the amount of disturbed snow surface by having vehicles follow the path of the lead vehicle as much as possible
	8.3 Preserve the aesthetic value of the areas surrounding traverse routes by limiting the placement of markers and flags to those quantities needed to maintain safe operations
	8.4 Avoid the discharge of wastewater to the maximum extent practical
	8.5 Deny use of USAP resources by NGOs

Table 7-1. Summary of Mitigating Measures

Aspect	Mitigating Measure
Impact Monitoring (9.0)	9.1 Perform an environmental review of all planned traverse field operations and research efforts to identify those activities which may have the potential to yield impacts to the environment. Develop appropriate mitigating measures with traverse planners accordingly
	9.2 Develop a comprehensive monitoring plan for traverse activities which identifies the temporal and spatial parameters to be measured to assess impacts
	9.3 Incorporate traverse activities into the *Permit Reporting Program* to document activities conducted each year that can be used to evaluate environmental impacts (e.g., fuel combustion, waste generation, environmental releases)
	9.4 Audit USAP traverse activities as a whole annually to (1) verify that activities are being performed as planned, (2) collect data to provide a comparison of the measured or observed impacts to the predicted impacts, and (3) suggest or develop corrective actions as necessary to mitigate increased or unexpected impacts
	9.5 Record the locations of traverse activities, including a description and quantity of: • materials remaining in the field (e.g., caches), • releases to the environment from operations • releases to the environment from scientific research • accidental releases (e.g., spills)
Hazardous Material Management (10.0)	10.1 Store all materials containing hazardous materials (i.e., Designated Pollutants) in containers which are compatible with the contents and are structurally adequate to accommodate the handling and stresses associated with transport on the traverse
	10.2 Utilize bulk fuel storage tanks specifically designed for transportation applications which include protection against structural damage if filled tanks are transported over rough terrain
	10.3 Limit materials containing Designated Pollutants (e.g., fuel, oil, glycol) used for traverse activities and personnel support operations to the types and amounts needed, including adequate safety margins
	10.4 Minimize the storage of materials containing Designated Pollutants in the field during the austral winter. If Designated Pollutants, equipment, supplies, or wastes are temporarily stored along the traverse route during the operating season or during the austral winter: • Mark and document storage locations to prevent the materials from becoming lost • Store containers (e.g., tanks, drums) in a manner to prevent them from becoming encrusted in snow and ice and possibly damaged upon retrieval • Store containers in a manner to prevent accidental releases to the environment (e.g., secondary containment) • Recover and return all items to a supporting USAP facility for disposition by the end of the following austral summer season

Table 7-1. Summary of Mitigating Measures

Aspect	Mitigating Measure
Waste Management (11.0)	11.1 Provide resources (e.g., containers) to manage all wastes generated during the traverse consistent with the requirements of the *Waste Management Plan and Users Guidance* and: • Contain all wastes to avoid releases to the environment (e.g., light objects being scattered by the wind) • Segregate and label Antarctic Hazardous waste and nonhazardous waste streams • Secure wastes during transport
	11.2 Inspect Antarctic Hazardous waste containers for leakage or deterioration on a weekly basis and document the inspections per the *NSF Waste regulation* (45 CFR §671.11(b))
	11.3 If practical, containerize all sanitary wastewater and greywater for transport to a supporting facility. If transport of sanitary wastewater is not practical, only discharge urine and greywater (per 45 CFR 671) and containerize human solid waste (see mitigating measure 4.2).
	11.4 Minimize the storage of nonhazardous wastes and Antarctic Hazardous wastes in the field during the austral winter. If wastes are temporarily stored along the traverse route during the operating season or during the austral winter: • Mark and record storage locations to prevent the materials from becoming lost • Store containers (e.g., tanks, drums) in a manner to prevent them from becoming encrusted in snow and ice and possibly damaged upon retrieval • Store containers in a manner to prevent accidental releases to the environment (e.g., secondary containment) • Return all wastes cached during the austral winter to a supporting USAP facility for disposition by the end of the following austral summer season

7.3 Environmental Reporting and Review

All activities associated with the use of surface traverses that relate to potential environmental impacts and compliance with U.S. environmental regulations will be documented and systematically evaluated. For example, the U.S. Waste Regulation (45 CFR §671) is applicable to all U. S. activities in Antarctica. The Waste Regulation establishes requirements for the issuance of Permits and associated reporting with respect to the management of Designated Pollutants (i.e., hazardous materials), the management and disposition of wastes generated in Antarctica, and release of any substances into the environment. Pursuant to the Waste Regulation, NSF has issued the *USAP Master Permit* (reference 3) to the civilian support contractor, Raytheon Polar Services Company (RPSC) for the period 1 October 1999 through 30 September 2004. The current Permit is expected to be renewed on 1 October 2004. Traverse activities conducted in Antarctica will be subject to the terms and conditions of the applicable *USAP Master Permit.*

By 30 June of each year, RPSC (the Permit holder) prepares the *Annual Report for the USAP Master Permit* documenting activities conducted for the previous 12-month period at permanent stations and individual outlying facilities and field sites, regarding waste management and releases to the environment. All traverse activities related to wastes and releases will be included in the Annual Report. In addition, the Permit holder will conduct an annual review to verify that the activities described in the Master Permit including those associated with any traverses are accurate and representative. Any revised conditions and significant changes will be identified and documented accordingly in subsequent *Amendments to the USAP Master Permit.*

The Permit holder has established a formal process to gather data needed for Permit reporting purposes known as the *Permit Reporting Program.* The program was designed to collect Permit-related information in an efficient and consistent manner addressing all activities conducted under the Permit at each permanent station and each individual outlying facility operated in the USAP. Relevant information pertaining to traverse activities will be included in the *Permit Reporting Program* for subsequent use in the *Annual Report for the USAP Master Permit* and the *Amendments to the USAP Master Permit*.

Data obtained through the *Permit Reporting Program* will also be used to characterize activities and conditions that are used both to assess and monitor environmental impacts. For example, Permit-related parameters that are reported and evaluated each year include fuel consumption and associated air emissions, waste generation and disposition, and planned and accidental releases to the environment. These parameters will be reviewed to identify conditions which are significantly different than those described in the *USAP Master Permit*. Data pertaining to traverses and regularly obtained through the *Permit Reporting Program* will be evaluated based on the conditions and potential impacts assessed in this Comprehensive Environmental Evaluation.

8.0 GAPS IN KNOWLEDGE AND UNCERTAINTIES

8.1 Introduction

The scope of this environmental review was designed to primarily focus on the operational aspects of conducting traverse activities in Antarctica. Specialized activities specific to a single project (e.g., instrument deployment, sample collection, construction of a new facility) and not in common with general traverse activities will require subsequent characterization and supplemental environmental review. This chapter describes several basic assumptions associated with the USAP's intention to develop and implement a traverse capability and identifies data gaps or uncertainties that may affect this evaluation of impacts.

8.2 Basic Assumptions

The development and use of surface traverse capabilities is certain to provide measurable benefits to the USAP. The traverse capabilities that are being considered represent a known and viable transport mechanism that would be used to optimally complement, not replace, existing airlift resources. The availability of both surface traverse and airlift transport capabilities would allow the USAP to select an efficient and environmentally sensitive method which is best suited for the intended mission.

For many years, other nations have successfully performed traverses to re-supply inland facilities in Antarctica using equipment and procedures similar to the proposed action. It has also been proven that traverses are a useful tool for the performance of scientific research, as indicated by the history of Antarctic traverses by many nations, including those performed recently as part of the extensive International Trans Antarctic Scientific Expedition (ITASE).

The extent that the USAP may utilize the proposed traverse capabilities in a given year is dependent on the variable logistical and research needs of the program. Similarly, the extent of field support resources that will be provided will be dependent upon the specific needs of the traverse mission. It is expected that McMurdo Station resources would provide most of the support to future USAP traverse operations, and some traverse missions may also utilize USAP field support resources such as airlift transported supplies, field caches, or airdrops. The levels of external support evaluated in this environmental review are representative of the available USAP resources expected to be used to support traverse activities for the foreseeable future. Because these support activities must be planned and scheduled well in advance, activities involving impacts which are substantially different that those identified in this environmental review would be assessed separately.

This environmental review focuses on the mechanical aspects of performing traverse or surface-based survey activities for re-supply or science-related purposes. These activities are comparable to the vast Antarctic traverse experience of the international community. There is no indication that the basic parameters used to characterize these traverse activities or associated support activities will change significantly from the conditions identified and evaluated in this review. Future traverse activities which would be performed under operating conditions or environmental settings that are significantly different than those described in this CEE would undergo supplemental environmental review. Therefore, there are no major data gaps or uncertainties related to the development and implementation of traverse capabilities that could materially affect the conclusions of this environmental review.

8.3 Uncertainties

The technical information related to the proposed action and evaluated in this environmental review was derived from two examples, a McMurdo to South Pole re-supply proof of concept traverse currently under evaluation, and the operational performance data from the recent ITASE traverse performed by the USAP. Based on data from these examples, potential environmental impacts for traverse operations were identified and evaluated relevant to the environmental conditions defined in this CEE. Uncertainties may exist with respect to the performance of traverse activities that occur under conditions different than those as characterized by the examples.

Traverse operating conditions which have the potential to influence the evaluation of environmental impacts include the route, equipment, and logistical approach. Impacts associated within a range of operating conditions have been characterized in this review; therefore, any variations are not expected to significantly affect the output of the activities or alter the conclusions. The following identifies possible data gaps or uncertainties in these areas.

The specific route that may be utilized in the future for either re-supply or scientific research missions is dependent on the specific needs of the USAP at the time the traverse is planned. This environmental review focused on potential impacts in three broad snow or ice-covered areas including the Ross Ice Shelf, the Transantarctic Mountains, and the Polar Plateau. Proposed traverse activities in areas significantly different than these such as Antarctic Specially Protected Areas or ice-free areas would require supplemental environmental review. Along a specific route, the extent of terrain alteration activities that may be needed for a traverse is dependent on the local environmental conditions including crevasses, sastrugi, and snow drifts. The number and size of crevasses that may require mitigation by filling for safe passage cannot be predicted nor can the extent of surface grooming needed for safe and efficient passage of the traverse equipment.

The number, type, size, and configuration of traverse equipment that would comprise a particular traverse activity are dependent on the needs of the mission. The configuration of equipment evaluated in this environmental review is representative of typical USAP traverse activities in the foreseeable future. It is expected that the configuration of future traverse missions would incorporate factors currently under proof of concept evaluation and would utilize operating experience gained from previous traverse missions performed by the U.S. and others.

Each surface traverse conducted by the USAP will require development of a customized operating strategy designed to meet the specific objectives of the mission. Operating parameters that may affect the nature and intensity of proposed traverse activities and influence related impacts include:

- Number of traverse trips (single, roundtrip, multiple)
- Operating schedule (total duration, number of travel hours per day)
- Number of people (operators, scientists)
- Number of traverse stops (temporary camps, rest stops, research locations)
- Substances released to the environment (exhaust emissions, wastewater discharge)
- Field maintenance and repair activities
- Use of temporary field storage areas for traverse equipment, fuel, or supplies

There is a large range and combination of operating parameters that may be considered for any particular traverse mission. The operating parameters evaluated in this environmental review are representative of typical USAP traverse activities for the foreseeable future.

8.4 Estimation Methods

Uncertainty is inherent in the methods that were used in this environmental review to estimate releases to the environment. Generic models were used to estimate fuel combustion exhaust emissions from traverse equipment and the potential discharge of wastewater in snow and ice-covered areas.

Generic emissions models were used to estimate exhaust gas emissions since actual testing data for traverse equipment operating under Antarctic conditions are not available. Emission factors were selected to best represent the type and size of equipment being characterized. In general, these models are used by regulatory authorities and risk assessors to provide estimates of exhaust emissions. Because these models do not account for fuel combustion efficiencies or emission standards that may be met by currently available equipment, the emission factors generally represent a conservative estimate, therefore actual emissions are expected to be less.

The projected quantity of wastewater that could potentially be discharged and the resulting pollutant loadings were quantified using per capita wastewater production rates developed for field operations and described in the *USAP Master Permit*. These models are applied to USAP operations throughout Antarctica for Permit reporting purposes and are reviewed each year. Inaccuracies in the estimates derived from these models are not expected to affect the conclusions derived from this environmental review. To the maximum extent practical, wastewater discharges will be avoided.

9.0 CONCLUSIONS

9.1 Introduction

This Comprehensive Environmental Evaluation (CEE) identified the potential impacts associated with the development and implementation of surface traverse capabilities by the USAP. The scope of the proposed action is unique because it encompasses all traverse operations that may be performed by the USAP not just those exclusively for a specific purpose (re-supply, science-related research), only for a designated period of time, or along a single route.

The USAP proposes to use surface traverse capabilities in conjunction with existing airlift resources to efficiently transport cargo and conduct field-related scientific research in a safe and environmentally responsive manner. Currently the USAP does not possess a robust and fully mature traverse capability. The traverse activities that the USAP has accomplished to date have been done on a very limited scale using available equipment that may not be the best suited for the intended application.

Potential environmental impacts associated with typical surface traverse activities were identified and evaluated using two scenarios. The first example involved the re-supply of the Amundsen-Scott Station from McMurdo Station using traverse methods currently undergoing engineering evaluation in a proof of concept study. To evaluate potential impacts associated with scientific traverses and surface-based surveys, the International Trans Antarctic Scientific Expedition (ITASE) of which the USAP is a participant was selected as a second representative example for the use of the traverse capability.

The methods used to identify and evaluate the impacts of the proposed activities are consistent with the *Guidelines for Environmental Impact Assessment in Antarctica* (reference 17) and are similar to those used in recent CEEs prepared for similar types of proposed activities in Antarctica, including the Draft *Comprehensive Environmental Evaluation for ANDRILL* (reference 18) and the *Comprehensive Environmental Impact Evaluation for Recovering a Deep Ice Core in Dronning Maud Land, Antarctica* (reference 19). In addition, the methods are consistent with those used for two preliminary assessments of the environmental impacts for traverse activities performed by the Australian National Antarctic Research Expedition, *Preliminary Assessment Of Environmental Impacts of Autumn Traverse From Mawson Station To LGB6, 250 Km To The South, To Depot Fuel For The PCMEGA Expedition In The 2002/03 Summer* (reference 20) and *Preliminary Assessment of Environmental Impacts PCMGA Expedition In The 2002/03 Summer* (reference 21).

9.2 Benefits of the Proposed Action

The proposed action is intended to supplement the USAP's current airlift capability to transport cargo and support in-field scientific research. Benefits realized by the implementation of a traverse capability include:

- The availability of a transport option that may be better suited than aircraft for certain types of cargo (e.g., size, weight), logistical needs, environmental conditions (e.g., severe weather), or in-field research requirements.
- Reduced fuel consumption for re-supply missions, since each tractor can haul approximately twice the cargo as a fully laden LC-130 for the same fuel investment. Less fuel consumed directly relates to fewer exhaust gas air emissions.
- Reduced reliance on airlift resources that may facilitate a reduction in the number of missions or allow the aircraft to become available for other purposes.

- Ability to operate under a broader range of Antarctic conditions than aircraft. If needed, traverse equipment may be able to operate earlier and later during an austral summer season than aircraft.
- Reduced station-based cargo handling support because re-supply traverse personnel may be used to load and unload cargo.
- Established traverse routes may provide proven corridors to facilitate and enhance in-field scientific research.
- Robust traverse capabilities may provide the resources needed to conduct more comprehensive in-field research.

9.3 Physical Disturbances to the Snow/Ice Environment

The traverse activities being considered in this environmental review would only occur on snow and ice covered areas. By the nature of the proposed action, traverse activities would unavoidably disturb the surface of the terrain. Although the disturbance would be primarily confined to the width of the traverse route, the impact may be more than minor since the route could extend hundreds of kilometers. The number of reoccurring traverses on a particular route remains unknown as it depends on the intended goals of the mission. Depending on the route, crevasses which cannot be avoided would be filled with native snow and ice to facilitate safe passage of the traverse equipment. The natural processes of wind action and snow accumulation will obliterate visual evidence of vehicle traffic over a short period of time resulting in only a temporary impact. Physical disturbance impacts caused by proposed USAP traverse activities on areas containing ice sheets, glaciers, and the Polar Plateau are therefore considered to be low.

Undoubtedly, the performance of surface traverses will cause physical disturbances to the Antarctic environment and alter the wilderness value. These disturbances will be transitory and consistent with present and historical uses of traverse resources to foster the progress of Antarctic exploration. It is expected that the physical benefits derived from the use of traverse resources by the USAP for scientific research and operational support will far exceed any diminishment of the pristine character of the environment.

9.4 Air Emissions

The combustion of fuel and the resulting release of exhaust byproducts to the atmosphere will be an unavoidable consequence of the proposed action to conduct surface traverse operations using mechanized equipment. Although the volume of fuel consumed and the resulting air emissions may be significant for a particular traverse mission, the exhaust gases and particulates are expected to rapidly dissipate in the atmosphere downwind along the extent of the traverse route. These emissions may be visually noticeable or detectable near their sources, but the emissions are not expected to pose a long-term or adverse impact to the air quality or surface albedo.

Exhaust emissions resulting from the combustion of fuel during traverse activities are expected to be transitory and dissipate as the traverse proceeds along the route. For comparison, the air quality at McMurdo Station, which uses considerably more fuel in one year than a typical traverse, was monitored continuously for a year and was found to be well below the Ambient Air Quality Standards in the United States. This suggests that if the stationary sources at McMurdo Station do not adversely impact the environment, likewise the mobile sources on the traverse which use far less fuel would not have an adverse impact. In addition, to transport the same quantity of cargo, traverse operations use less fuel and emit far fewer exhaust emissions than the LC-130 aircraft currently used by the USAP in Antarctica.

9.5 Releases to Snow/Ice Environment

Various types of materials or substances may be released to the snow and ice environment either intentionally or accidentally during the performance of traverse activities. Objects deployed in the field to support traverse operations such as route marker flags may become encrusted in snow, lost, or deteriorate over time. It is anticipated that wastewater produced by traverse personnel will be containerized and transported to the maximum extent practical to a supporting USAP station for disposition. If wastewater must be discharged, it will only be released in areas allowed by the Antarctic Treaty. Wastewater, if discharged, will become permanently frozen in the snow, isolated below the surface, and will not pose a threat to human health or the environment. It is anticipated that abandoned objects will not contain hazardous materials and will not pose an adverse impact to the environment.

Throughout the progress of traverse operations, substantial quantities of fuel may be handled and used to operate traverse equipment as well as being transported as cargo. An accidental release such as spills or leaks of fuel or other hazardous materials (lubricants, coolants) cannot be predicted but represents a potential impact to the environment. However, spill prevention measures have been incorporated into the design of the equipment and traverse operating procedures. If a spill is detected, control measures can be rapidly implemented to respond to the incident. Fuel or other hazardous materials, which may be accidentally released on snow-covered terrain, would be expected to migrate vertically through the snow firn until reaching an impermeable surface where the material would spread laterally. In general, the USAP manages and transports large quantities of hazardous materials such as fuel on a daily basis and significant releases to the environment are relatively rare. If a spill occurs during a traverse operation, it has potential to affect the environment on a long-term but localized basis and it is expected that the released material would be isolated, limiting further migration.

9.6 Other Impacts

Implementation of the proposed traverse capabilities is expected to moderately affect operations at certain USAP stations and field camps involved with the traverse activities. Major operational conflicts or impacts will be avoided through advanced planning and resource scheduling.

Scientific research performed in the USAP will also be affected through the implementation of traverse capabilities. The impacts to science will be largely positive resulting from the use of the traverse capability to supplement existing airlift resources and provide new opportunities for research. Traverse activities will disturb the terrain but these impacts will be documented so that future research may be designed to avoid potential interferences.

USAP traverse activities will affect the social condition of the Antarctic environment represented by its wilderness value. The use of the traverse capability by the USAP will be isolated to specific routes and will be analogous to the traverse activities performed by other nations that operate in Antarctica. It is expected that the benefits realized by the USAP's use of traverse capabilities will far outweigh the localized and largely transient diminishment of the wilderness quality of the Antarctic environment.

9.7 Summary

The development and use of traverse capabilities by the USAP is a significant operational and scientific undertaking representing a major commitment of resources and potentially resulting in observable or measurable environmental impacts. The expected scientific and operational benefits related to the USAP's use of traverse capabilities have been thoroughly evaluated and are deemed to be substantial. The outputs (environmental impacts) resulting from the performance of traverse activities are well known, understood by numerous organizations that operate in Antarctica, and have been addressed in this CEE.

The USAP intends to use this CEE to address the potential impacts associated with the mechanical aspects of performing science-related or cargo transport traverses in Antarctica. Impacts associated with unique operations, specialized research techniques, or traverse routes which occur in areas (i.e., environmental settings) that are significantly different than those characterized in this CEE would be evaluated in supplemental environmental reviews.

The environmental impacts resulting from the performance of traverse activities may be more than minor or transitory but are localized along the traverse route. As realized by numerous other operators in Antarctica, the impacts associated with the use of surface traverse capabilities are relatively benign compared to the substantial benefits this transport mechanism offers. Overall, the projected impacts associated with the USAP's use of traverse capabilities were determined to be more than minor or transitory but the impacts would not result in a widespread adverse impact to the Antarctic environment.

10.0 NONTECHNICAL SUMMARY

This Comprehensive Environmental Evaluation was prepared by the National Science Foundation to evaluate potential impacts resulting from the proposed development and implementation of surface traverse capabilities by the USAP. The purpose of developing a surface traverse capability will be to enhance the USAP's current logistical support mechanism for the re-supply of facilities in Antarctica, specifically to provide a more capable alternate transportation method to complement the existing airlift resources. A second, yet equally important purpose for the implementation of surface traverse capabilities, will be the use of the traverse as a platform to perform advanced surface-based scientific studies in Antarctica. Overall, the implementation of a traverse capability would yield numerous benefits to the USAP, including decreased reliance on aircraft resources, increased opportunities to expand science in Antarctica, including the South Pole, and reduction in the quantity of fuel consumed to transport cargo and reduced air emissions resulting from the combustion of fossil fuels.

The methodology and equipment to conduct surface traverses in Antarctica is currently available. Various Antarctic Treaty nations, including the United States, have successfully performed traverses to meet numerous logistical and scientific goals. Currently the USAP does not possess a robust and fully mature traverse capability and can only perform surface traverses on a limited basis using existing resources. The intended use of the traverse capability to be developed by the USAP will be analogous to the traverse activities currently being performed by other nations that operate in Antarctica and are expected to continue in the future.

Description of Proposed Activities

The scope of the proposed action analyzed in this CEE is unique because it encompasses all traverse operations that may be performed by the USAP. Traverses may be designed for either re-supply or science-related research purposes and may utilize more than one traverse route. Surface traverses used for re-supply missions would typically be conducted between two primary facilities, following improved and marked routes, and would be used more than once. Traverses used for scientific purposes would follow routes that were selected to support the intended research and may be used only once.

Both types of surface traverses will typically involve the use of several motorized tracked vehicles towing sleds or trailers which contain fuel for the traverse equipment, living and working modules for the traverse crew, cargo, and other materials. Both re-supply and scientific traverses may stop each day of travel for rest, equipment inspection or repair, and scientific research. Each traverse would have the resources and equipment to refuel tractors, perform routine maintenance, and collect wastes for subsequent disposition at supporting stations. In some cases, sanitary wastewater may be discharged in snow-covered areas as allowed by the Antarctic Treaty.

The scale of re-supply and science traverses may be significantly different. Re-supply missions would involve the transport of deliverable payloads as well as the fuel and consumable supplies needed during the trip. For example, in an optimally configured re-supply mission from McMurdo Station to the South Pole, six tractors would be used, each capable of delivering approximately 20,000 to 27,000 kg of cargo while consuming approximately 20,000 liters of fuel on a 30-day roundtrip journey. To transport an equivalent amount of cargo to the South Pole from McMurdo Station, LC-130 aircraft would consume slightly less than twice as much fuel.

Unlike a re-supply traverse mission, a research traverse may require fewer and smaller tractors to transport the equipment and supplies needed to support the traverse crew and perform the intended research. Scientific traverses may depend on airdrops or strategically placed caches for periodic replenishment of consumable supplies. A typical scientific traverse may be conducted over a period of 40 days, using two tractors each consuming approximately 14,000 liters of fuel over the duration of the mission.

In this environmental review, the USAP has considered several alternatives for the proposed action. For re-supply purposes, Alternative A is an optimally configured system of traverse vehicles whose frequency of operation would complement existing airlift support mechanisms. Other alternatives considered included the development of the traverse capability and use of it on a minimal frequency basis only (Alternative B), under reduced intensity operating conditions (Alternative C), using minimal field support resources such as caches, depots, or airdrops (Alternative D), or only on established routes (Alternative E). The No Action Alternative, that is, not developing a surface traverse capability, was also considered and was designated as Alternative F. Several other alternatives were identified but were eliminated from detailed analysis because they failed to meet the required level of performance.

For science-related traverse activities or surface-based surveys, it is expected that the field activities will be specifically designed to support the proposed research; therefore, there are no relevant alternatives other than performing the research as proposed or not doing it at all.

Environmental Impacts

In this CEE, the USAP has addressed the potential impacts associated with the mechanical aspects of performing science-related or cargo transport traverses in Antarctica. The environmental setting for proposed traverse activities that was defined in this CEE included snow- and ice-covered areas of the Ross Ice Shelf, Transantarctic Mountains, and the Polar Plateau. Impacts associated with unique operations, specialized research techniques, or traverse routes which occur in sensitive areas or areas that are significantly different than those characterized in this CEE would be evaluated in supplemental environmental reviews.

Potential environmental impacts associated with typical surface traverse activities were identified and evaluated using two scenarios. The first example involved the re-supply of the Amundsen-Scott Station from McMurdo Station using traverse methods currently undergoing engineering evaluation in a proof of concept study. To evaluate potential impacts associated with scientific traverses and surface-based surveys, the International Trans Antarctic Scientific Expedition (ITASE) of which the USAP is a participant was selected as a second representative example for the use of the traverse capability.

By the nature of the proposed action, traverse activities will undoubtedly disturb the surface of the snow and ice-covered terrain. This disturbance would be primarily confined to the width of the traverse route and would be influenced by the number of reoccurring traverses on a particular route. Crevasses which cannot be avoided would be filled with native snow and ice to facilitate safe passage of the traverse equipment. The natural processes of wind action and snow accumulation will quickly remove any visual evidence of vehicle traffic resulting in only temporary impacts.

The use of mechanized equipment and the associated combustion of fuel will result in the unavoidable release of exhaust byproducts to the atmosphere. Traverse equipment will use less fuel and produce significantly fewer air emissions than aircraft transporting an equivalent amount of cargo. The exhaust gases and particulates are expected to dissipate in the atmosphere downwind of the traverse route. These emissions may be visually noticeable or detectable near traverse vehicles, but the emissions are not expected to pose a long-term or adverse impact to the air quality, surface albedo, or snow and ice chemistry.

Few releases to the snow and ice environment are expected as a result of traverse activities. Measures will be taken to prevent accidental spills of fuel, oil, glycol, or other hazardous substances used to support traverse activities, including materials stored in the field or transported by airdrop. Materials released during the course of traverse operations may include inert materials such as marker flags that will become encrusted in snow and ice. Wastewater may be discharged at various stopping points along the traverse route in areas allowed by the Antarctic Treaty and if it is not practical to containerize the material for further disposition. If wastewater is released, it would be sanitary wastewater and generally less than 7 liters per person per day. Wastewater discharged in the field would be isolated below the surface, become permanently frozen in the snow, and would not pose a threat to human health or the environment.

Surface traverse activities may result in other impacts. Operations at certain USAP stations and field camps involved with the traverse activities may be affected, but major operational conflicts will be avoided through advanced planning and resource scheduling. It is expected that mostly positive impacts to scientific research performed in the USAP will result from the new research opportunities provided by the traverse capabilities. Impacts resulting from traverse activities will be documented so that future research performed in Antarctica may be designed to avoid potential interferences from physical disturbances or releases. USAP traverse activities will also affect the social condition of the Antarctic environment represented by its wilderness value although these impacts will be localized, and the benefits realized by the USAP's use of traverse capabilities will far outweigh the resulting temporary impacts. The use of surface traverses by the USAP will continue the long-standing tradition of Antarctic exploration, in-field scientific research, and support of various facilities on the continent that are routinely performed by other nations.

Mitigating Measures and Monitoring

This CEE describes a number of measures that will be taken to mitigate (reduce or avoid) impacts to the environment and USAP operations resulting from the development and use of surface traverse capabilities. These mitigating measures have been designed to be effective and practical by addressing various aspects of traverse operations including:

- Traverse Routes
- Traverse Resources (equipment, personnel support resources, staffing)
- Physical disturbances to the snow and ice environment
- Air emissions
- Releases to the snow and ice environment
- Impacts to USAP Facilities and operations
- Impacts to scientific research in the USAP
- Impacts to social conditions of Antarctica

Provisions for most of the mitigating measures are developed during the planning and preparation stages of a traverse or surface-based survey activity and well before the actual field work is underway. During the planning and preparation stages, features are built into the design of the proposed traverse activity to ensure that the resources needed to conduct the traverse and mitigate potential impacts are available. Organizational impacts related to USAP facilities that may be involved in the proposed action will be effectively mitigated through advanced planning, scheduling, and allocation of resources and facilities.

Prior to the initiation of traverse activities, the USAP will develop an impact monitoring strategy to detect, if any, temporal and spatial changes caused by the proposed action. Environmental impact assessment and monitoring would be conducted during all phases of traverse operations, particularly during the planning stages to ensure that resources are adequately available to support mitigating measures and minimize environmental impacts.

Conclusions

The development and use of surface traverse capabilities by the USAP is a significant operational and scientific undertaking in the USAP representing a major commitment of resources. The benefits as well as the environmental impacts resulting from the performance of traverse activities are well known, understood by numerous organizations that operate in Antarctica, and have been addressed in this CEE.

The operational and scientific benefits expected from the USAP's use of traverse capabilities are deemed to be substantial and include:

- Availability of a transport option that may be more suitable under certain conditions than the exclusive use of aircraft
- Reduced fuel consumption and combustion exhaust air emissions
- Reduced reliance on airlift resources
- Ability to operate under a broader range of Antarctic conditions
- Availability of resources to expand the scope of in-field scientific research

The environmental impacts resulting from the use of surface traverse capabilities include:

- Physical disturbance to the snow and ice environment
- Release of fuel combustion byproducts (air emissions) to the atmosphere
- Minor releases of abandoned materials such as trail marker flags
- Possible releases of wastewater to snow and ice areas
- Potential accidental releases of fuel or other hazardous materials, or catastrophic losses of equipment and materials
- Impacts to operations at McMurdo Station and other USAP facilities
- Impacts to the wilderness value of Antarctica

The environmental impacts resulting from the use of surface traverse capabilities may be more than minor or transitory but will be localized along a designated traverse route. As realized by numerous other operators in Antarctica, the impacts associated with surface traverses are relatively benign compared to the substantial benefits this transport mechanism offers. Overall, the projected impacts associated with the USAP's use of traverse capabilities were determined to be more than minor or transitory but the impacts would not result in a widespread adverse impact to the Antarctic environment.

11.0 REFERENCES

1. National Science Foundation. *Adoption Of Standard Operating Procedures For Placement, Management, And Removal Of Materials Cached At Field Locations For The United States Antarctic Program.* Environmental Document and Finding of No Significant and Not More Than Minor or Transitory Environmental Impact. October 16, 1997.
2. McMurdo Area Users Committee. *Science Advantages of an Oversnow Traverse to Re-supply South Pole.* July 1, 2001.
3. National Science Foundation. *USAP Master Permit.* Permit Number 2000WM-01(RPSC) Mod. 1. March 23, 2000. Incorporates by reference the Master Permit Application dated 15 April 1999 and Permit Conditions dated 27 August 1999
4. National Science Foundation. *U.S. Antarctic Program, 2002-2003.*
5. National Science Foundation. *Historic Guide to Ross Island, Antarctica.* NSF 89-91 Booklet.
6. National Science Foundation. *Develop Proof Of Concept Traverse From McMurdo Station, Antarctica To The South Pole*. Environmental Document and Finding of No Significant and Not More Than Minor or Transitory Environmental Impact. October 15, 2002.
7. National Science Foundation. *Final Supplemental Environmental Impact Statement for the U.S. Antarctic Program.* October 1991.
8. U.S. EPA Office of Air and Radiation. *Compilation of Air Pollutant Emission Factors.* AP-42, Volume II, Mobile Sources, Fourth Edition. September 1985.
9. U.S. EPA National Vehicle and Fuel Emissions Laboratory. *Nonroad Emissions Model,* draft version, June 1998.
10. Lockheed Idaho Technologies Company. *FY 1994 Ambient Air Monitoring Report for McMurdo Station, Antarctica*. December 1994
11. Lawrence Berkeley National Laboratory. *Black Carbon Aerosol at McMurdo Station, Antarctica.* December 2000.
12. Magee Scientific Company. *Measurement of Combustion Effluent Aerosols from The South Pole Station.* Final Report. November 2000.
13. Magee Scientific Company. *Measurement of Combustion Effluent Carbonaceous Aerosols in the McMurdo Dry Valleys.* Report of Initial Findings. February 2001.
14. National Science Foundation. *Continued Use and Evaluation of Explosives to Support Scientific Research in Antarctica.* Environmental Document and Finding of No Significant and Not More Than Minor or Transitory Environmental Impact. November 14, 1995.
15. Raytheon Polar Services Company. *2003 Annual Report for the USAP Master Permit*. June 30, 2003.
16. Jamestown Marine Services, Inc. *Field Camp Oil Spill Response Guidebook.* August 1993.
17. Council of Managers of National Antarctic Programs (COMNAP). *Guidelines for Environmental Impact Assessment in Antarctica.* June 1999.
18. Alfred-Wegener Institute Foundation for Polar and Marine Research. *Comprehensive Environmental Impact Evaluation for Recovering a Deep Ice Core in Dronning Maud Land, Antarctica*, October 4, 2000.
19. McMurdo Sound Portfolio. *Draft Comprehensive Environmental Evaluation (CEE) for ANDRILL*. January 22, 2003.
20. Australian Antarctic Division, Australian National Antarctic Research Expedition. *Preliminary Assessment Of Environmental Impacts Autumn Traverse From Mawson Station To LGB6, 250 Km To The South, To Depot Fuel For The PCMEGA Expedition In The 2002/03 Summer.* 2002.
21. Australian Antarctic Division, Australian National Antarctic Research Expedition. *Preliminary Assessment of Environmental Impacts PCMGA Expedition in the 2002/03 Summer.* 2002.

12.0 APPENDICES

APPENDIX A
Analysis of McMurdo to South Pole Traverse as a Means to Increase LC-130 Availability in the USAP

APPENDIX B
US ITASE 2002-2003 Field Report

APPENDIX C
Air Emissions from Fuel Combustion Sources

Appendix C

Air Emissions from Fuel Combustion Sources